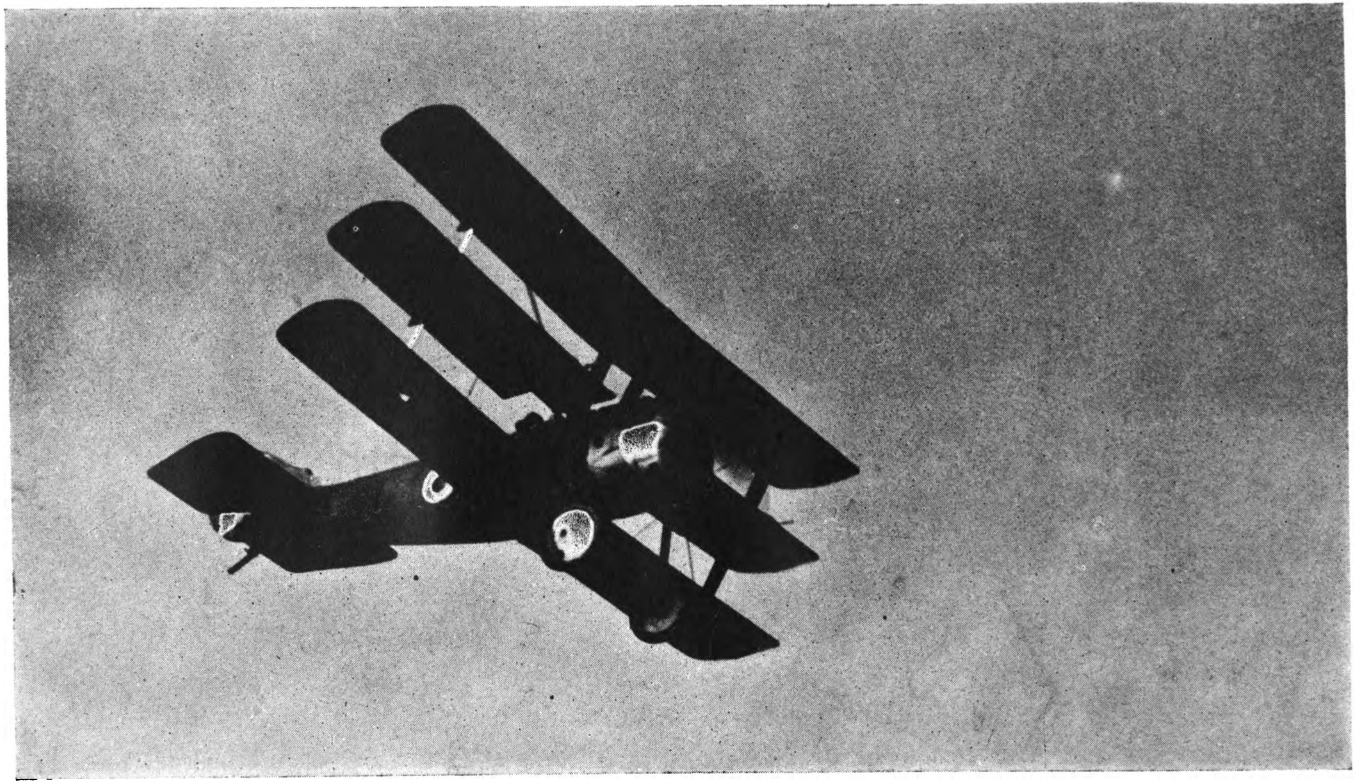
AEROPLANE CONSTRUCTION AND ASSEMBLY

J. T. KING N. W. LESLIE



ON PATROL

AEROPLANE CONSTRUCTION AND ASSEMBLY

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FOREWORD

The purpose of this Instruction Manual on Aeroplane Construction and Rigging is to give Aviation Mechanics an essentially practical understanding of the work that they will be expected to carry out.

It is also written to serve as a guide to Aviation Instructors following a course from the elementary principles of an aeroplane to its completed stage ready for flight; involving the nomenclature, materials, structural features, the assembling and alignment of same.

INTRODUCTION

An aeroplane is designed to withstand the strains put upon it by the work which it is called upon to do.

It is a machine of accurate yet delicate construction and great care must be taken that no undue strains are put upon it. An aeroplane rigger must necessarily have a fine conception of where any heavy strains may be placed upon it without causing distortion or breakages to its structural parts.

To the average layman, an aeroplane is a solid mechanical structure, and he has no preference in lifting any part of it, other than that of convenience. Some machines are marked with arrows denoting the points at which loads may be applied, but it is necessary for any aeroplane rigger to have a thorough knowledge of all these points and the reasons why loads may be applied at same. Frequently the machines have no load marks whatever and the aviation mechanic must naturally use his own judgment.

In climbing into the passenger's or pilot's seat, care must be taken not to place any weight on the trailing edge or unsupported fabric of the plane. There is a reenforced section called the sidewalk on the wing next to the fuselage generally covered with corrugated rubber, upon which the weight may be placed. There is also a step in the side of the fuselage.

In turning a machine around by hand, it is necessary to lift the tail post off the ground. In doing this, care must be taken to apply the lift under the *load* points. These points are the intersection points of the fuselage struts with the longerons and if not marked their positions must be determined before an attempt is made to raise the tail.

In applying lift to the panels, always lift directly under the points where the struts are attached to the wing beams. Were a strain to be placed upon the leading or trailing edges a permanent distortion would take place in the ribs of the wing. In the case of lifting on a trailing edge, which is made of flattened steel tubing, a permanent flexure would be given to it, spoiling the efficiency and disturbing the alignment of the machine.

A good rigger is more than a cog in the wheel in relation to the labors of an aerodrome's routine. He is an essential factor and his work determines the safety of those who fly the machines that are under his care.

In the event of engine trouble and the aeroplane having the altitude, a well rigged and balanced aeroplane will automatically

take its own gliding angle and act efficiently as a parachute with the additional advantage that the landing ground may be chosen. If, through the fault of bad workmanship in rigging, some part should collapse, the pilot and passenger are helpless.

An efficient rigger should use care, accuracy and conscientious application in carrying out all the duties that befall him.

The rigging of aeroplanes is an art and the aeroplane is a comparatively new invention. The scope of its field is unbounded. Let the prospective rigger keep this in mind, that the scope of his future may be high above the average tradesman.

AEROPLANE ASSEMBLY

NOMENCLATURE.

The parts of an aeroplane are so named as to designate the function they perform.

The letters T., F., or S., prefixed to names of parts in this book, refer to Top, Front, or Side views of the plane as shown in accompanying cuts. The prefixed number refers to the part number as shown on the cut.

T. 1. AILERON—A small wing situated at the outward end of the trailing edge, the operation of which turns an aeroplane about its longitudinal axis; causes an aeroplane to tilt sideways.

S. 2. AXLE—Seamless steel tubing with reinforced wood filler.

S. 3. AXLE COLLAR—Machined brass, used to prevent wheels from coming off.

S. 4. AXLE COLLAR BOLT—Hexagon head, passes through axle collar and axle, and is secured by castellated nut.

S.F. 5. BRACES—Horizontal, stabilizer, steel tubing streamlined with spruce form, and covered with linen tape and doped.

S. 6. CONTROL WHEEL—Two in one, controls ailerons and elevators.

S. 7. CONTROL YOKE—Non-magnetic aluminum tubing, fastened to seat rails by two trunions and bearings, and to which control wheel is secured.

S.T. 8. COCKPIT—Pilot's, padded.

T. 9. COWL—Top engine, sheet aluminum secured to the side cowling by two straps and buckles.

F. 10. COWL—Bottom, sheet aluminum.

F. 11. CLIPS—Fuselage, hold compression struts, fuselage diagonal bracing wires are also attached.

T. 12. DISTANCE PIECE—A long, round piece of spruce running full length of wing and used to prevent ribs from rolling over.

T. 13. ELEVATOR—A controlling surface usually hinged to the rear of the tail-plane the operation of which directs an aeroplane upwards or downwards.

S.T.F. 14. ENGINE SECTION PANEL—Upper wings are attached to engine section panel.

S. 15. ENGINE BED—Four laminations, two center spruce, outside hardwood, are used as engine supports.

S. 16. ENGINE BED PROTECTOR—One thirty-second inch sheet steel wrapped around bed to prevent engine from sinking into wood.

S.T. 17. EDGE LEADING—The front edge of a surface relative to its normal direction of motion.

T. 17a. EDGE LEADING FORM—Spruce.

T. 18. EDGE TRAILING—The rear edge of a surface relative to its normal direction of motion.

T. 18a. EDGE TRAILING FORM—Flattened steel tubing.

T. 19. FABRIC—Irish linen, shrunk and tightened by applying about six coats of dope and two of varnish.

T.S. 20. FIN, VERTICAL—A fixed vertical surface, used as a keel, and to prevent the machine from tail-spinning.

S. 20a. FIN, VERTICAL FORM—Flattened steel tubing.

S.T. 21. FUSELAGE—The body of the aeroplane holding the engine, fuel, pilot, and passenger, and to which is fastened the panels and tail unit.

T. 22. FAIR LEAD—Used to prevent sway of control wires.

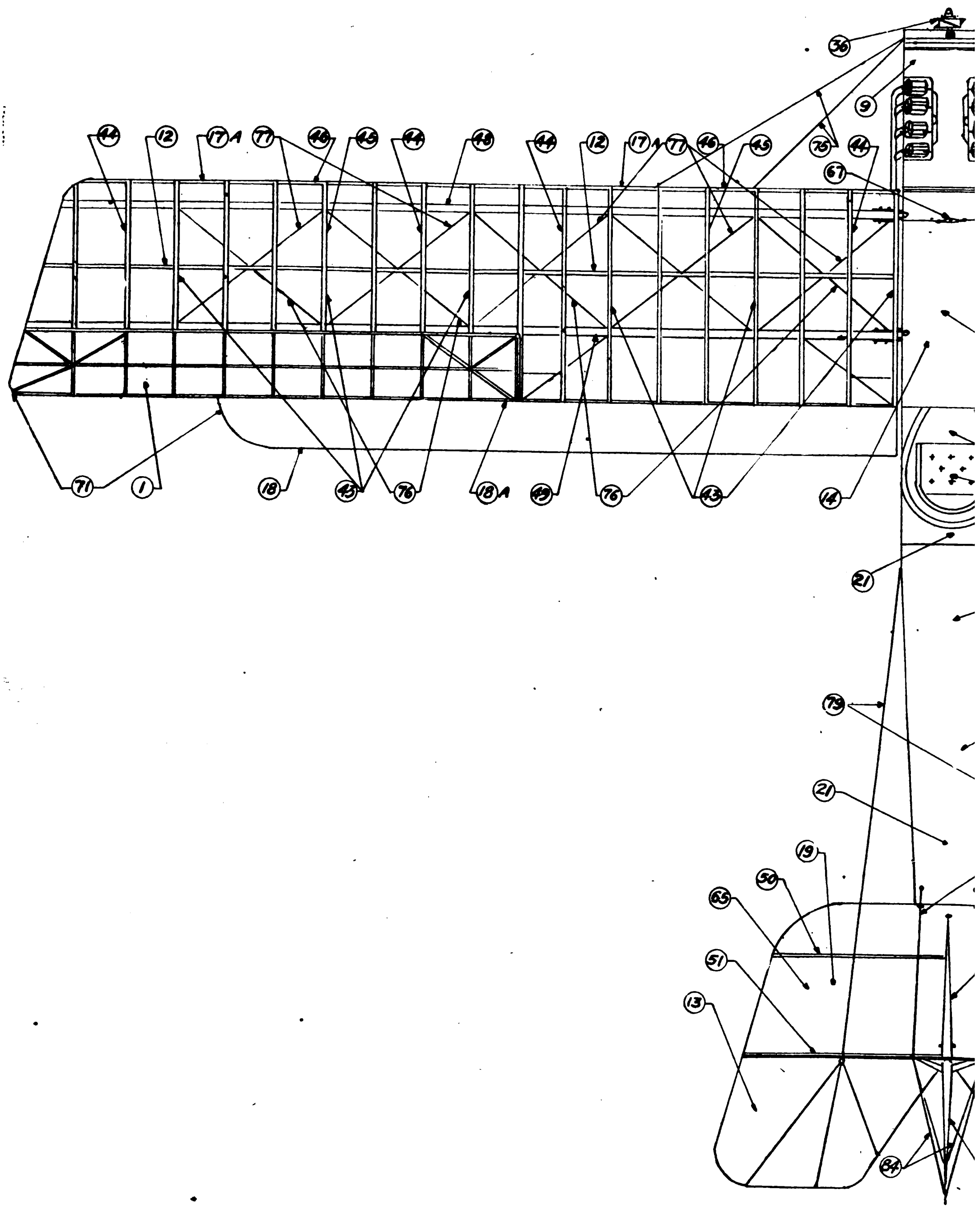
S. 23. FLOOR BOARD—Pilots, made of hard wood, used to attach rudder bar to.

S. 23a. FLOOR BOARD—Passenger.

S. 24. GASOLINE SIGHT GAUGE—Showing quantity of fuel in tank.

S. 25. GASOLINE TANK—Heavy gauge tin.

F. 26. GAP—The vertical distance between the upper and lower wings of a biplane.



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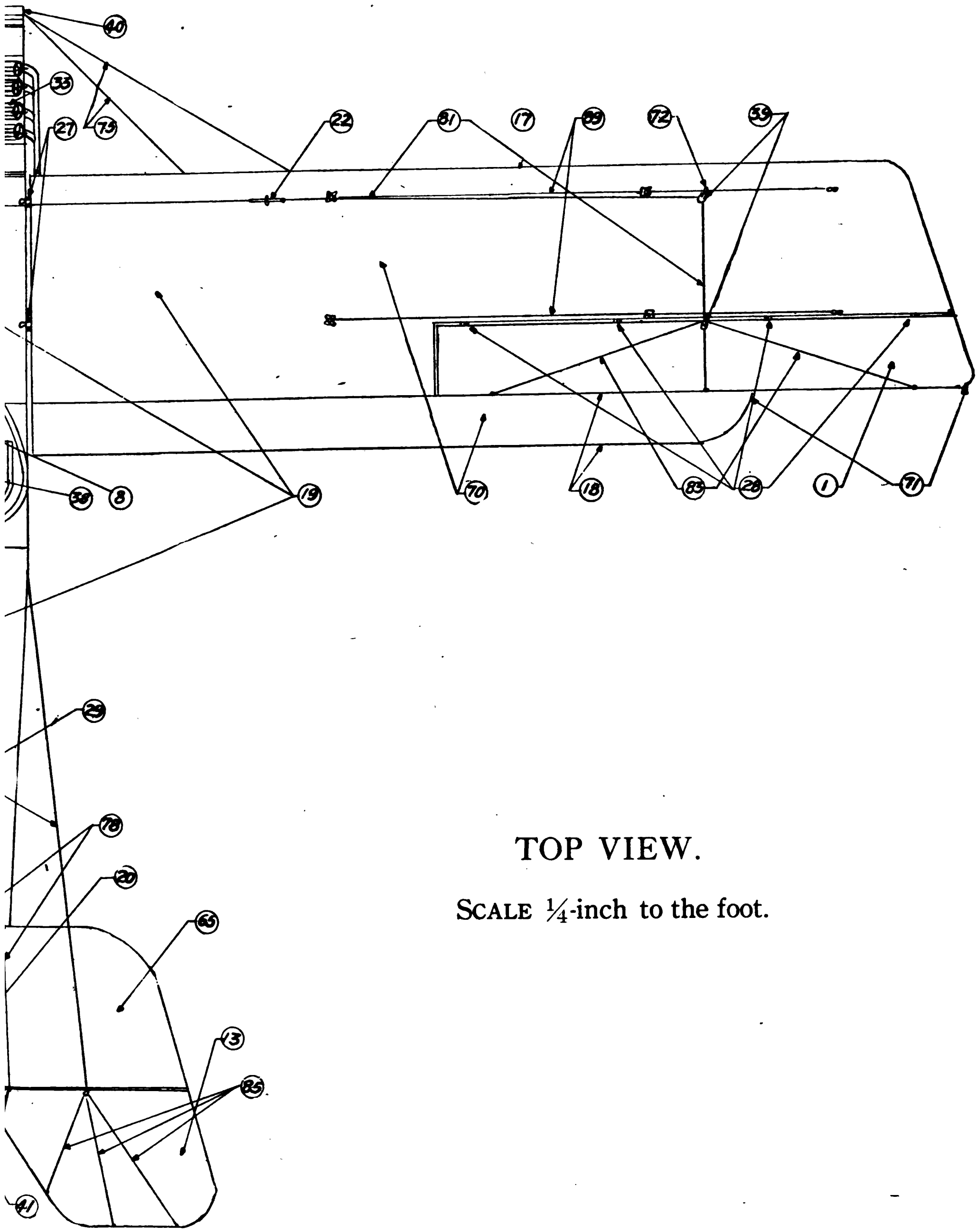


TOP VIEW.

SCALE ¼-inch to the foot.

F.S.T. 27. HINGES, WING—Female on panels, male on engine section and connected by wing hinge pin.

T. 28. HINGES, AILERON—Male and female, used to connect aileron to panel by a hinge pin.

T.S. 29. INSPECTION COVER—An accessible streamline cover, fastened to upper longerons by four hinges on each side, can easily be removed to inspect control wires and fuselage bracing wires.

S.F. 30. KING POSTS OR CONTROL POSTS—Used on controlling surfaces as a lever for control wires.

S. 31. LONGERON—Generally white ash, running the full length of the fuselage and around which all the body of the machine is built up.

S.F. 32. LANDING WHEELS—Tangent wire wheel, pneumatic tires, spokes and rim covered by doped fabric to streamline wheels.

F.T. 33. MOTOR—Power-plant used to propel aeroplane.

S. 34. NOSE-PLATE—Shaped sheet steel, used to connect four longerons and holds radiator in place.

F. 35. PITOT-TUBE HEAD—The air passes through head and metal tubing to indicator, which measures the velocity of an aircraft with reference to the air through which it is moving, usually calibrated in miles per hour.

F.T. 36. PROPELLER—Oak, mahogany, or walnut, five laminations so shaped that its rotation about an axis produces a force (thrust) in the direction of its axis. Includes both pusher and a tractor prop.
PANEL OR PLANE—See wing.

F. 37. PROPELLER HUB—Machined steel, connects prop to crank shaft.

S.T. 38. PILOT'S SEAT—Upholstered bucket seat.

S. 38a. PASSENGER'S SEAT—Upholstered bucket seat.

T. 39. PULLEY—Aileron compensating wire, ball-bearing pulley through which wire passes without friction.

F.T. 40. RADIATOR—Contains four and one-half gallons of water, used to cool motor.

S.F.T. 41. RUDDER—A hinged or pivoted surface attached to the rear of tractor machine. Used to steer a course or direction.

S 41a. RUDDER FRAME—Flattened steel tubing.

S. 42. RUDDER BAR—Pilot's and passenger's, is dual control, ash bar, copper tipped, mounted in center on a swivel and each end connected to a control cable running to rudder.

T. 43. RIB, COMPRESSION—Acts as a lightened rib, besides bearing the stress of compression produced by the tension of the internal bracing wires.

T. 44. RIB, LIGHTENED—A curved wooden part assembled in a panel and used to give the panel its curvature and convey the lift from the fabric to the spars.

T. 45. RIB NOSE—Same purpose as forty-four but runs from leading edge form to front of main spar only.

T. 46. RIB, NOSE FORM—Three-ply wood, a curved form on top of forty-four, its purposes being to take fabric and keep it to its proper curvature and prevent its sagging.

S. 47. SEAT RAIL—Spruce I-beam running from station behind pilot's seat to station in front of passenger's seat, supports pilot's and passenger's seats, also see No. 7.

T. 48. SPAR, MAIN—Spruce I-beam within a panel and to which all ribs, drift and anti-drift wires are attached.

T. 49. SPAR, REAR—Same as forty-eight except situated in rear portion of panel.

T. 50. SPAR, TAIL PLANE MAIN—Same purposes as forty-eight.

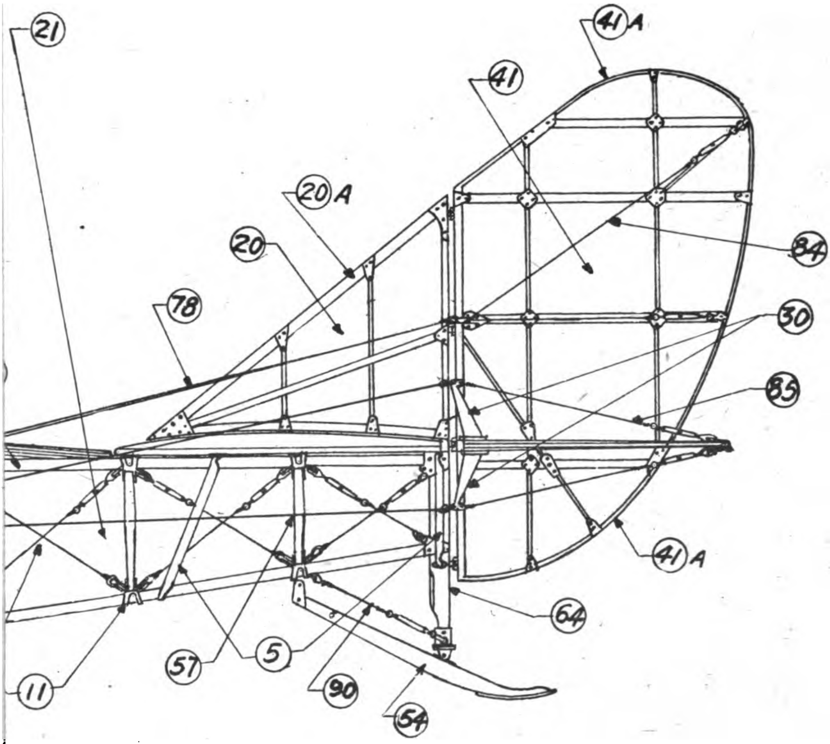
T. 51. SPAR, TAIL PLANE REAR—For same purposes as fifty but of lighter construction, elevator is attached to it by hinges.

F. 52. SHOCK ABSORBER, LANDING GEAR—Two pieces of rubber ten feet long, absorbs and minimizes the shock of a landing.

53. SHOCK ABSORBER, TAIL SKID—Rubber, same as fifty-two only situated at rear of machine.

S. 54. SKID, TAIL—Made of white ash or other hardwood. Carries weight of rear portion of machine while on the ground, also acts as brake in landing.

F. 54a. SKID, WINGS—Made of rattan. Protects and keeps wing tips from ground in case of bad landing.



VIEW. SCALE ½-inch to the foot.

F. 55. STRUTS, WING—Made of spruce because it has a high compression strain for its weight. Used to keep upper and lower planes apart.

S.F. 56. STRUT, ENGINE SECTION—Spruce, holds engine section panel to which upper planes are attached.

S. 57. STRUT, FUSELAGE—Spruce, acts as spacer and keeps the four fuselage longerons apart.

S.F. 58. STRUT, LANDING GEAR, FRONT—Spruce, reinforced by binding with linen twine.

S. 59. STRUT, LANDING GEAR, REAR—Same as fifty-eight.

F. 60. STREAM-LINE SPACER—Used as a stream lining for axle, also acts as a spacer for wheels.

S. 61. SOCKET, LANDING GEAR, FRONT—Made of sheet steel, used to connect landing gear strut to fuselage.

S. 62. SOCKET, LANDING GEAR, REAR—Same as sixty-one.

S. 63. SOCKET, ENGINE SECTION STRUT—Sheet steel, holds engine section strut, fuselage strut and diagonal bracing wires.

S. 64. TAIL POST—White ash laminated, sometimes spruce. Vertical post finishing the streamline effect of the fuselage, and to which the four longerons are secured. The universal joint of tail skid and two hinges of rudder are also fastened.

T. 65. TAIL PLANE—A horizontal stabilizing surface attached by bolts to rear portion of fuselage and to which the elevators are attached.

F.S. 66. TURNBUCKLE FORK—BARREL—Brass with an alloy of manganese. Forked end with right hand thread always attached to fixed portion of the machine and an eye end which is attached to loop of cable.

T. 67. TURNBUCKLE, EYE—Used to connect two wires, so two eyes are used instead of one fork.

F.S. 68. WINDING, LANDING GEAR STRUT—Bound with linen twine to reinforce and prevent splintering.

S. 69. WIND SCREEN—Made of celluloid with aluminum frame, used to deflect wind and oil from passenger or pilot.

F.T. 70. WING—The supporting surfaces of an aeroplane.

F.T. 71. WING TIP—The extreme right or left hand end of a wing.

F.T. 72. WING MASTS—Spruce with copper banding at each end, used as a truss for cable which supports upper wing extensions when machine is on the ground.

F. 73. WIRES, LANDING—Stranded steel cable, used to take load of wings when machine is landing or on the ground, also used for adjusting dihedral angle of machine.

F. 74. WIRES, FLYING—Duplicated stranded steel cable, used to take load of machine while flying, these wires prevent wings from folding upwards when flying.

F.T. 75. WIRES, DRIFT—Stranded steel cable, used to prevent wings from folding backwards when flying.

T. 76. WIRES, ANTI-DRIFT—Piano wire, diagonal bracing wires used to adjust wing framework and to hold rigid.

T. 77. WIRE, DRIFT (WING)—Piano wire, same purposes as seventy-six.

S.T. 78. WIRE, RUDDER CONTROL—Flexible stranded steel cable, used to connect rudder-bar to king-posts of rudder.

S.T. 79. WIRE, ELEVATOR CONTROL—Flexible stranded steel cable, used to connect control yoke to king-posts of elevators.

F. 80. WIRE, AILERON CONTROL—Flexible stranded steel cable, used to connect control wheel to aileron king-posts.

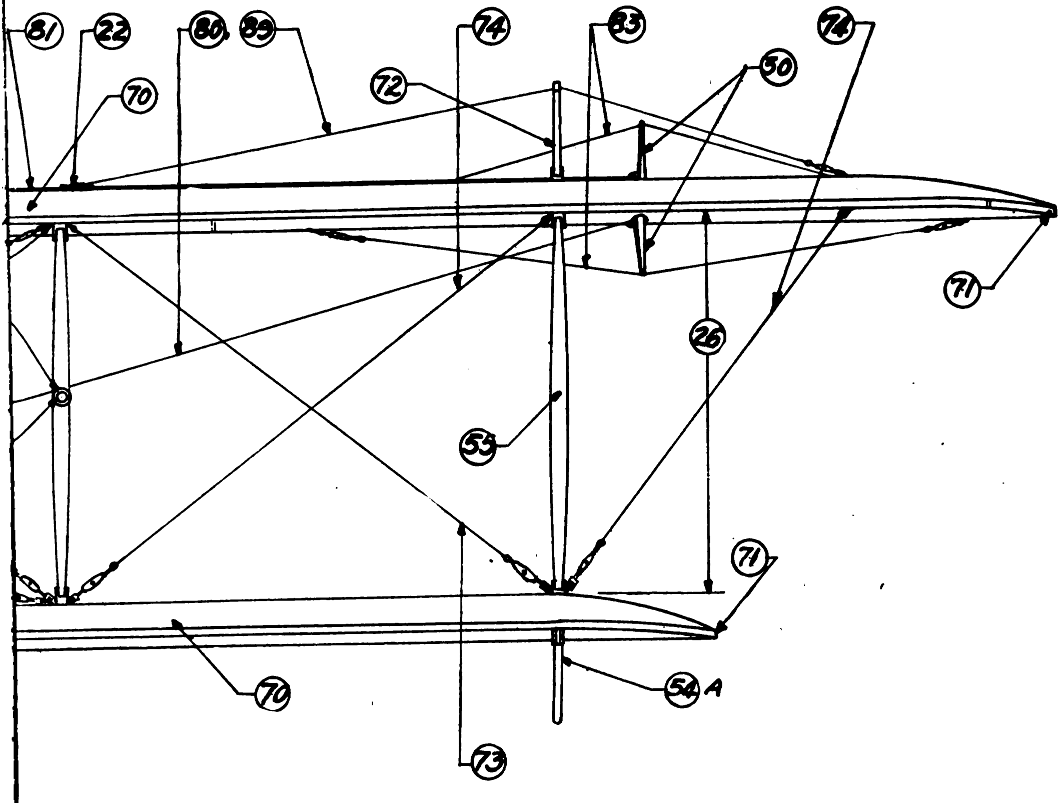
T.F. 81. WIRE, AILERON COMPENSATING—Flexible stranded steel cable, used to balance and adjust ailerons.

S. 82. WIRE, FUSELAGE, DIAGONAL BRACING—Forward half of fuselage are duplicated stranded steel cables, rear half are piano wires.

F.T. 83. WIRE, AILERON CONTROL BRACING—Piano wire, used to brace control-posts, and to prevent warping of ailerons.

S.T. 84. WIRE, RUDDER CONTROL BRACING—Piano wire, same function as eighty-three.

F.T.S. 85. WIRE, ELEVATOR CONTROL BRACING—Same function as eighty-three.



FRONT VIEW. SCALE 3/8-inch to the foot.

F. 86. WIRE, LANDING GEAR DIAGONAL BRACING—Heavy stranded steel cable, used to hold landing gear rigid and to take strains in landing.

S. 87. WIRE ENGINE SECTION BRACING—Heavy stranded steel cable used to adjust stagger on engine section.

F. 88. WIRE, ENGINE SECTION DIAGONAL BRACING—Heavy stranded steel cable, used to hold engine section rigid and take strain of machine both when on the ground and flying.

F.T. 89. WIRE, OVERHANG—Stranded steel cable, runs over wing mast and takes load of extension when machine is on the ground.

S. 90. WIRE, TAIL POST BRACING—Piano wire, used to brace tail post and take strain from tail posts in a fast landing.

S. 91. WIRE, ENGINE SECTION TIE—Stranded steel cable, used to connect engine section struts from spreading.

TYPES OF AEROPLANES:

MONOPLANE. Having one main lifting surface.

BIPLANE. Having two main lifting surfaces mounted one above the other.

TRIPLANE. Having three main lifting surfaces mounted one above the other.

TRACTOR. A tractor aeroplane is drawn forward by means of a propeller placed in front of the main lifting surfaces.

PUSHER. A pusher aeroplane is thrust forward by means of a propeller at the rear of the main lifting surfaces.

AEROPLANE. A land machine equipped with a landing gear with free running wheels, which enable it to take off and land on the earth.

HYDRO-AEROPLANE. A water machine equipped with either single or double floats which enables it to take off and alight on water.

FLYING BOAT. Equipped with a boat shaped hull which takes the place of fuselage and pontoons of a Hydro-Aeroplane.

TERMS USED IN THE ALIGNMENT OF AEROPLANES WITH DEFINITIONS:

The LEADING EDGE and TRAILING EDGE are terms used to designate the front and rear of all planeing and controlling surfaces.

The CURVE OF A WING is the form given to its upper surface.

CAMBER is the form given to its lower surface and its dimension is determined by placing a straight edge against its leading and trailing edges and measuring its maximum depth.

CHORD. The distance measured along a straight line from the leading to the trailing edge.

GAP. The vertical distance between the upper surface of the lower plane to the lower surface of the upper plane.

STAGGER. The projection of the leading edge of one plane over the leading edge of another plane. Its dimensions can be determined by dropping a plumb bob from the leading edge of the upper plane and measuring the horizontal distance from the leading edge of lower plane to the plumb line. It is essential that the machine should be supported rigidly in its true flying position.

INCIDENCE. The angle that the planes make with the horizontal when the machine is in true flying position. Where the lower plane is assembled on the fuselage it is definitely fixed.

To determine and check the incidence angle:

Having the machine in flying position, place a straight edge against a determined point on the rear beam having a spirit level on the straight edge. Level straight edge then measure the vertical distance from the straight edge to a determined point on the front beam. Check the incidence at three different points on each wing.

SPAN. The distance from wing tip to wing tip on the main plane.

FLYING POSITION. When the machine is in a true horizontal plane. This can be got by leveling the engine beds and supporting the rear of fuselage with a trestle.

EXTENSION OR OVERHANG. The projection of the span of the upper plane beyond the lower plane.

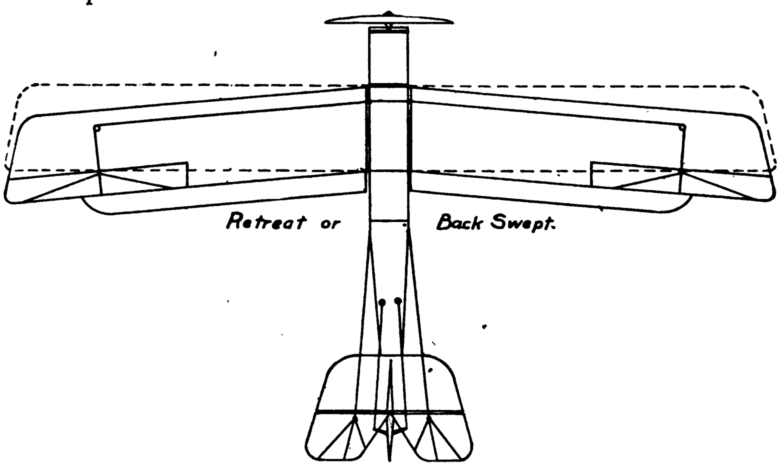
DIHEDRAL. The inclination of the wings with a horizontal transverse line.

The angle is taken from the point of intersection of the main planes with the engine section panel.

ASPECT RATIO. The relation of the Chord to the Span. The efficiency of a machine is increased with a high aspect ratio.

DECLATURE. Is present when the Chord of the lower plane is smaller than the Chord of the upper plane.

DECALAGE. Is an increase in the angle of incidence of the upper plane with reference to the angle of incidence of the lower plane.



BACK SWEEP OR RETREAT. The acute angle that the planes make with the longitudinal axis.

INHERENT STABILITY. An inherently stable machine is one which is so constructed that it will stabilize itself directionally, longitudinally and laterally.

AUTOMATIC STABILITY. The stability given to a machine by its movable planeing surfaces controlled by the aviator.

KEEL SURFACE. The vertical projection when the machine is seen in side elevation.

LONGITUDINAL DIHEDRAL. The angle the main planes make with the horizontal stabilizer. This essential factor gives fore and aft stability to the machine. The angle of incidence on the horizontal stabilizer is never greater than one-third that on the main planes.

STREAM-LINE. The form given to an object that offers the least resistance to the passage of the object through the air.

WASH-IN OR DROOP. When the Incidence angle is increased toward the wing tip.

WASH-OUT. The reverse of "wash-in."

AEROPLANE ASSEMBLY AND ALIGNMENT.

As this is the most important part of an aeroplane rigger's work, it will be necessary to follow the method of alignment and assembly from receiving the machine from the makers and working methodically until the aeroplane is ready for active service.

As the Curtiss JN-4 is an ideal training machine, we will use this machine for the purpose of illustration and the experience and practice gained can be applied to any type of aeroplane, irrespective of the size and type of the machine. The methods and principles of alignment are the same, the only differences being the definite dimensions of the dihedral angle and the stagger. These can be determined from the manufacturers' specifications.

For transportation the complete machine is shipped from the Aeroplane Factory in two long boxes. Illustration (1)

The packing cases usually come on flat cars, the four cases containing two complete aeroplanes per flat car. If facilities for hoisting the cases off the car are available, attach the sling at the point of balance, which is indicated in Illustration by a large arrow painted on the sides of the packing cases. When a hoist is not available, use skids, rollers, and crowbars to unload the cases.

It is sometimes necessary to transport the packing cases from the railway siding to the Hangars. This is accomplished by means of heavy duty trucks, and the heaviest end of the packing case should be placed on the truck first. The cases being much longer than the truck and the engine being in the heavy end, there would be a danger, were the heavy end of the packing case to extend beyond the truck body, of its falling out and causing serious damage to the engine and fuselage.

Before unloading from the truck, select a level piece of ground on which to place the packing case. It is a good policy to unload the case marked "Fuselage" first, placing it in a position where there is ample room for the assembling and attaching of the wings.

The packing cases are of the knock-down type. Remove the top, the sides and the ends of the case. A careful mechanic will draw the nails and wood screws from these sections in order to prevent accidents. These sections are carefully put aside ready for shipment.

Illustration No. 2 shows the Fuselage resting upon a cradle and firmly braced.

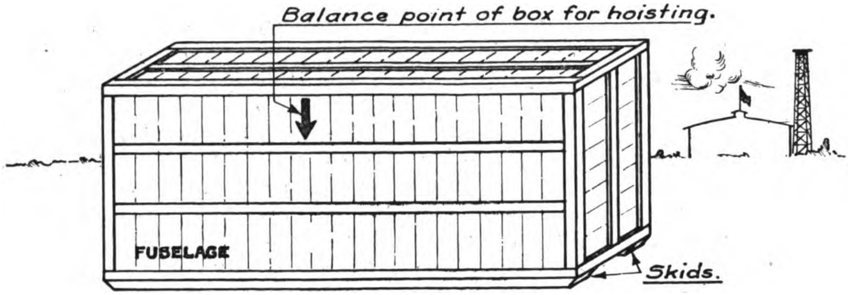
The "Fuselage" packing case contains the complete Fuselage with the engine installed, the running gear completely assembled with the exception of the wheels. Due to the limited packing space these are secured in some convenient

space in the case. The propeller is secured by a bolt through the propeller hub. A tool box fastened to the bottom of the case contains the special engine tools, propeller puller and propeller socket wrenches, exhaust manifolds and gaskets, hot air stoves and the warm air flexible tubes.

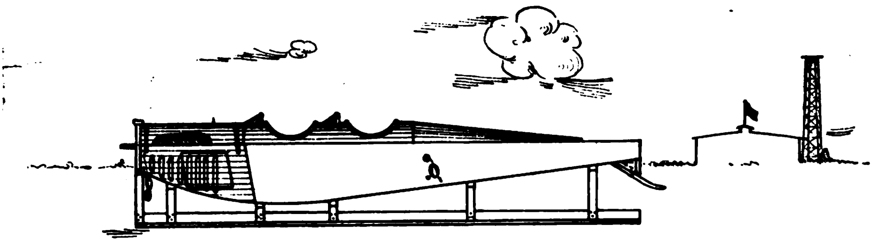
The bolts and nuts necessary to assemble the hot air stoves, exhaust manifolds, safety wire for the locking of turnbuckles, and the cotter pins for securing the hinge pins and castellated nuts, after complete assembly, are also contained in the tool box. The packing sheets should be carefully checked before attempting to assemble the machine.

The fuselage is now in an accessible position and ready for the assembling of the main sections. It is now necessary to open the case marked "Wing Panels." Place the wing panel case on its side with the "open here" mark uppermost. Remove this side using the same precaution as used in opening the fuselage case. This case contains, the horizontal stabilizer, right and left elevators, vertical stabilizer and rudder, engine section panel, engine section panel struts, wing struts, wing masts, wing skids, horizontal stabilizer braces, the aileron elevator and rudder control posts. The four remaining layers consist of the right and left lower panels, and the right and left upper panels. The different parts may be readily examined as they are taken from the packing case. The fabric is closely inspected for tears, dents or abrasions to the finish. The strut socket fittings and wing plate fittings are now examined more easily than when the machine is completely assembled. The bolts should bear evenly and make a snug fit, and where possible the heads should be on **top**. The castellated nuts should be pulled up to the proper tension and securely locked with a cotter pin. The cables are examined for kinks and rust. As the various parts are taken out of the case they are checked with the packing sheet.

The first step in assembling will be to attach the engine section struts. Strut No. 1 will be placed on the left front, No. 2 on the right front, No. 3 on the right rear and No. 4 on the left rear. (Owing to the incidence angle of the planes the rear engine section struts are shorter than the front struts.) Remove the bolts from the engine strut sockets. When inserting the struts do not injure the copper sheeting on the end of struts. All struts should make a perfect fit and bear evenly on their bases. As the struts are under compression they should distribute their loads evenly. If they do not fit perfectly they are liable to split. Insert the bolts in their respective holes and as the cotter pin holes have been drilled on assembly to insure a good fit, the castellated nut should be placed on the bolt from which it was taken. Raise the engine section panel into position on top of the engine section struts,

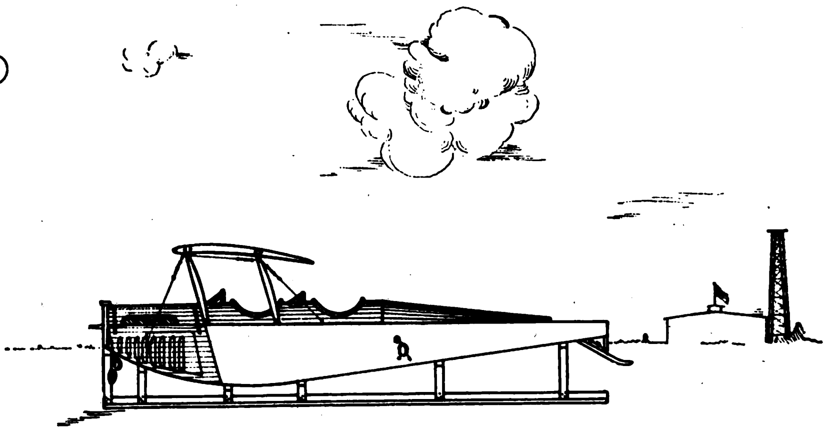


1 TYPICAL AEROPLANE BOX.



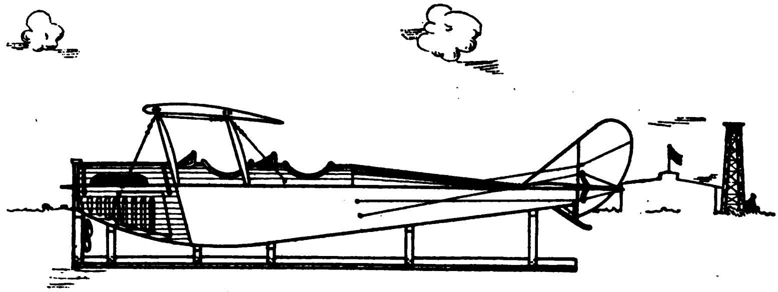
UNPACKING FUSELAGE.

2



ASSEMBLY OF ENGINE SECTION STRUTS, PANEL & BRACE WIRES.

3



ASSEMBLY OF TAIL UNIT & CONTROL WIRES.

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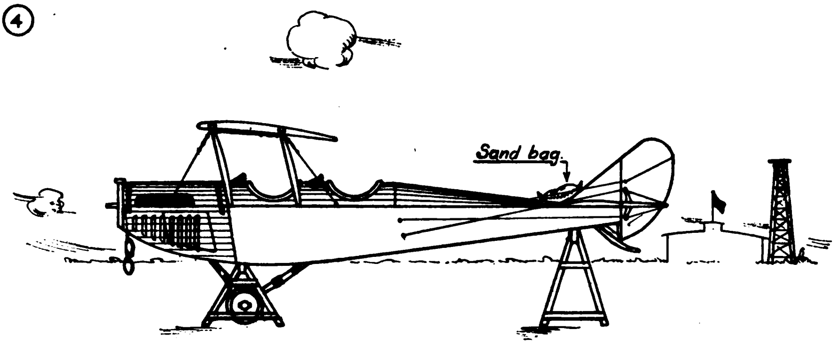

ASSEMBLY OF RUNNING GEAR.

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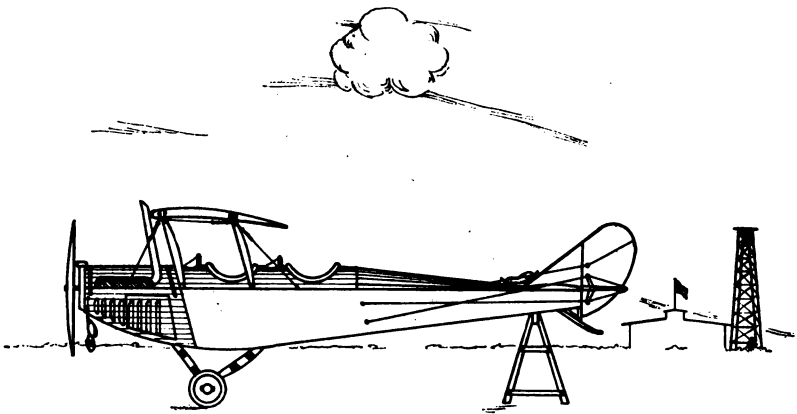


FUSELAGE NOW READY FOR ASSEMBLY OF WINGS.

(6)

insert the bolts through the strut socket fittings and lock the nuts. Attach the rear engine section bracing wires, starting the turnbuckle barrel evenly on both the right and left hand threads. Tighten the turnbuckles till both right and left hand threads are just covered. Attach the front engine section bracing wires in a similar manner. Connect the diagonal bracing wires and adjust them until the engine section panel and struts are true about the lateral axis of the machine. This is obtained by adjusting the diagonal bracing wires until they are equal in length and tension. Two methods may be used in checking this alignment.

First, by means of trammel points; second, by means of a steel tape. Sometimes it is impossible to take the length of the diagonal bracing wires. In such case measure equal distances from definite points down the front right and left struts; then take the diagonal measurements from these points.

The empennage or tail unit is assembled with the fuselage in this position for the same reason that the engine section panel was assembled, and that is, accessibility. The control posts come tied in pairs, and are labeled for their respective positions; namely, the aileron control posts, the rudder control posts and the elevator control posts. On the tag they will be marked "upper left" or "lower left," and the "upper right" or "lower right." Before assembling the tail unit these control posts should be attached. Their bracing wires should be brought to the proper tension, and any warps in these surfaces should be taken out by the turnbuckles on the bracing wires.

The easiest method of attaching the control posts is to place the surface on a pair of trestles which enables work to be done on both sides of the surface at once.

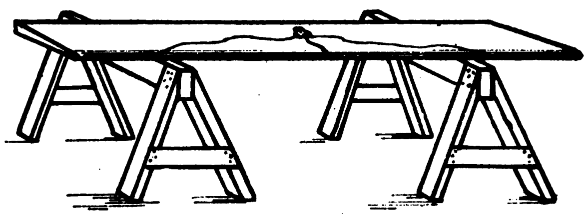


Fig. 1-A.

Illustration: Lock the turnbuckles and remove the inspection cover by withdrawing the cotter pins from the hinges. The horizontal stabilizer may now be assembled. Remove the castellated nuts and clevises from the "U" bolts; also the nuts from the two bolts on the tail post fitting. The horizontal stabilizer is then placed in position on these bolts. Care should be taken that all bolts should be properly aligned

in their respective holes. The clevises act both as a tie and as a washer. The castellated nuts are screwed down to an even tension on all bolts. The horizontal stabilizer braces are

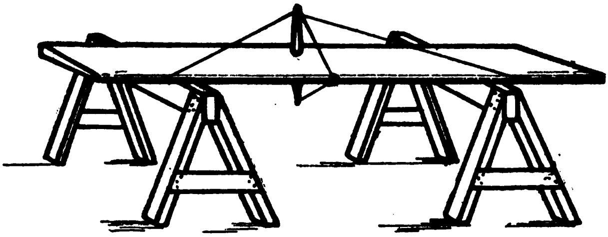
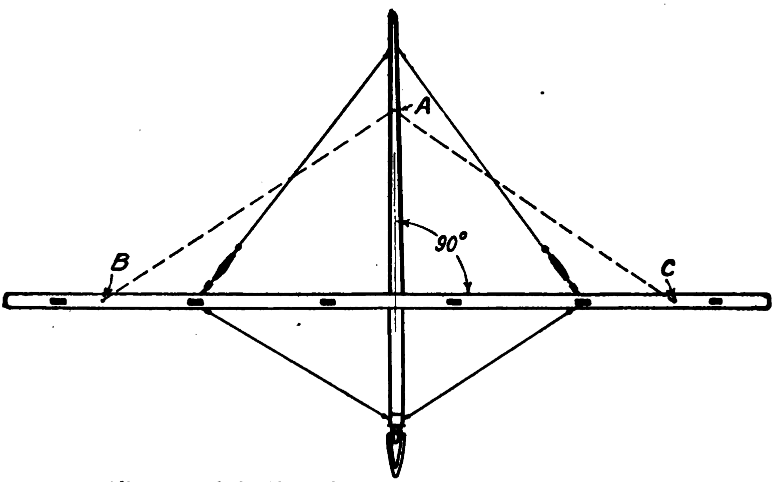


Fig. 1-B.
ASSEMBLING CONTROL POST AND BRACE WIRES

attached, and as these braces are not adjustable, they hold the horizontal stabilizer rigidly in position.

The vertical stabilizer is secured by a bolt in front running through the front beam in the horizontal stabilizer, and at the rear by the bolts connectng the horizontal stabilizer and the tail post. A welded fitting on the vertical stabilizer is attached to these bolts. The vertical stabilizer is trued up by means of the vertical stabilizer bracing wires. Since the vertical stabilizer is set at 90 degrees to the horizontal stabilizer, it is only necessary to adjust the bracing wires on each side to equal length and tension. These lengths are checked by means of a steel tape.



Alignment of the Vertical Stabilizer and Horizontal Stabilizer.
AB should be adjusted by the turnbuckles until they equal distance AC.

A simple method of checking the alignment of the vertical stabilizer is that of using a steel square proving the right angle at the base. Lock the turnbuckles. The rudder is then attached, by means of hinge pins, to the vertical stabilizer and tail post. These hinge pins secure the male and female hinges. The pins are securely locked by cotter pins. As the rudder makes a close fit to the vertical stabilizer and tail post a 1/16x 1/2 cotter pin should be used. This, when bent, allows the free movement of the rudder and prevents shearing of cotter pins. This applies to all the controlling surfaces on the machine. It is an advantage to put the middle hinge pin in first because often an extra application of dope on the fabric will shrink it unevenly, which may put a small bend in the beam or steel tubing, thus throwing the hinges out of alignment. In this way the top and bottom hinges can be aligned and the hinge pins inserted easily.

Before attaching the rudder control cables, it will be necessary to replace the inspection cover because the rudder control cables run through two rawhide fair leads in the inspection cover. Before replacing the cover an examination of the longerons, fittings and diagonal bracing wires can be made. Be sure that all turnbuckles are locked and that threads are fully engaged. As piano wire is used here for the bracing wires extending from the pilot's seat to the tail post, they should all be painted for the prevention of rust. Where the diagonal bracing wires intersect, in each section, insulating tape is wrapped so as to bind the two wires together. This will prevent vibration of the wires. The diagonal bracing wires in the engine section of fuselage are made of stranded steel cable and should always be bound with tape to prevent vibration.

The rudder control cables are double, but should not be twisted. Find the top cables attached to the rudder bar and follow through the fuselage making sure that they have a straight lead and do not foul any of the internal bracing wires. Run them through the fair leads on the inspection cover and attach them by the shackles to the rudder control posts.

The right and left elevators are the last parts of the tail unit to be attached, and as the control posts and their bracing wires have been assembled, it will be only necessary to insert the hinge pins, using the method explained in the attaching of the rudder. After inserting the hinge pin in the middle of an elevator, the remaining hinges are often difficult to align. An easy method to employ is to let the elevator hang down at approximately 90 degrees to the horizontal stabilizer. Extra leverage can be exerted on both the stabilizer and the elevator and then the hinge pins can be easily inserted. Heads of pins should be outward. The elevators are much more easily assembled in this

way, and it also facilitates the inspection of pins before flights, the advantage being that the exact location of the *cotter pins* is known.

Connect the elevator control cables making sure that they cross. Connect the cables from the bottom of the control yoke to the top of the elevator control posts first. These cables take the weight off the elevators, and take the strain off the hinges. Next connect the control cables from the top attachment of the control yoke to the bottom elevator control posts. The elevators and rudder are now ready to be aligned.

Since the turnbuckles for adjusting the elevator and rudder control cables terminate in the pilot's seat, adjustments are made for surfaces from this position. An efficient rigger will take with him the locking wire and all the necessary tools to make these adjustments. The rudder control cables being double, adjust the cables on the bottom first. It will only be necessary to bring the top cables to the same tension as the bottom cables. Place the feet on each side of the rudder bar making sure that the rudder bar is at 90 degrees to the center line, or at right angles to the fore and aft line of the fuselage. This is called the "neutral" position.. Then sight along the rear of the fuselage and determine if the rudder is in line with the vertical stabilizer. If, with the rudder bar neutral, the rudder is seen to be turned slightly to the left, loosen the bottom left turnbuckle and tighten the bottom right turnbuckle the same number of turns until the rudder is perfectly stream-lined. Bring the top control cables to the same tension on both sides of the fuselage. There should be a small amount of play in these control cables due to the fact that the slip stream from the propeller places extra tension on them when the machine is in flight, and if they are adjusted with too great a tension, it will increase the labors of the pilot in flying the machine.

An experienced pilot must know the amount of pressure he is exerting when turning the rudder, and by having all the control cables too tight he loses this essential sense of *feeling*. There should be approximately a quarter of an inch of play in the rudder control cables. Lock these turnbuckles and wrap insulating tape around each pair, starting at the forked ends and finishing at the loops of the cables.

To Adjust the Elevator Control Cables:

As the control cables attached to the bottom of the control yoke are now taking the weight of the elevators, adjust these first. Tighten the turnbuckles until the threads are covered by the barrel of the turnbuckle. This is an essential point. Never use a turnbuckle with any threads showing for the reason that it would not have its maximum strength. The accuracy in the length and splicing of the cables will now bring the elevators very

near to their true alignment. Push the control yoke forward. This depresses the elevators. Now sight along the rear of the fuselage, then draw the control yoke towards you raising the elevators. The elevators should now be seen as a single line, both elevators showing the same amount of surface. Adjust the turnbuckles until you get this result. Bring the elevators to the neutral position, or in other words, until they are in perfect stream-line with the horizontal stabilizer. Adjust the cables on the upper attachment of the control yoke on each side to the same length and tension.

This is the position in which the tension on these control cables may be adjusted. The tension on the upper and lower control cables should be the same. The tension on these cables must not be great for the same reason as stated in adjusting the rudder control cables. Owing to the center of gravity being situated slightly ahead of the center of pressure a well balanced aeroplane automatically takes its own gliding angle when the engine is throttled down to 400 R. P. M. Therefore the pilot does not require such a wide range of control in depressing the nose of the machine. The control yoke, when the elevators are neutral, should be slightly forward. This will be seen to give the pilot a much greater control in raising the nose of the aeroplane.

Lock the turnbuckles, and check the alignment again. If the machine has dual control, it will be necessary to get in the front seat to adjust the rudder bar parallel to the rudder bar in the rear seat. Adjust the cables until they have the same tension and until the rudder bars are parallel to each other, then lock the turnbuckles. There are no adjustments to be made on the elevator control because the two control yokes are connected by two distance rods made of steel tubing. The rods are of equal length. Make sure that the connections are properly locked and move freely.

THE ASSEMBLY OF THE RUNNING GEAR:

The running gear will come assembled, with the exception of the wheels. Take off the axle collars and the brass washers. Clean the axle and the hubs of the wheels thoroughly. If the wheels have grease cups see that they are filled and give them a turn down. By looking in the hub it can be ascertained if the hole from the grease cup has been stopped up. Place one brass washer on the axle, then give the axle a coat of hard grease; put on the wheel, then another brass washer; slip on the axle collar; align hole and insert the bolt, putting the head of the bolt up if possible. Lock the castellated nut with a cotter pint. Repeat this operation on the other wheel. Now place a 4x4 under the longerons at the point where the fuselage and struts intersect. This will be where the aluminum side cowl ends. Have a man hold the tail of the machine. Then detail four men on each side

of the fuselage to raise the front end of the fuselage from the cradle on which it was resting, the man at the rear of the machine pulling down. Place a trestle under each end of the 4x4 and a trestle under the rear end of fuselage. Be sure the top of the trestle is padded and placed under a load point. To release the man that is still holding the tail, place a bag of sand on top of the front beam of the horizontal stabilizer or some heavy weight tied to the tail skid. The 4x4 is now situated at the point of balance, and if the tail were not tied down the machine would be liable to go over on its nose. Take the cradle out of the way and wheel the running gear under the fuselage.

No time should be lost in assembling the running gear on the machine. If the work is being done in the open a strong wind may come up at any time and cause damage. Bring the running gear into place. See that all diagonal bracing wires are slack. The running gear strut sockets should fit tightly with the longeron plate fittings. On this machine special lock washers are placed under the heads of bolts in the form of clips which prevent the heads of the bolts from turning while the castellated nuts are being screwed on. Be sure that all these nuts are pulled up *tight* and locked.

ALIGNMENT OF THE RUNNING GEAR:

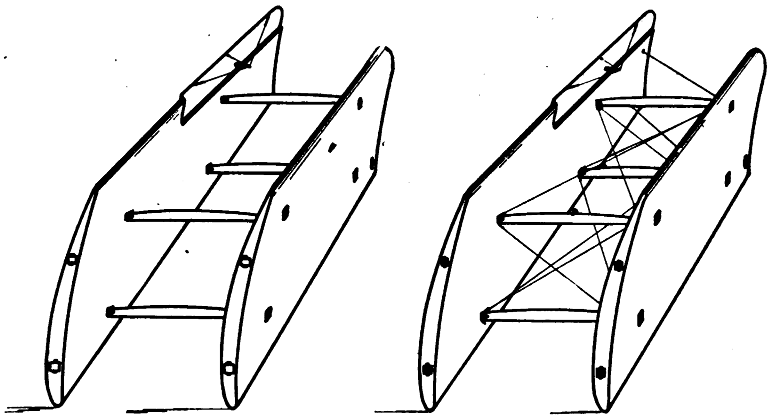
The running gear is trued up by the diagonal method, that is by having the diagonal bracing wires of equal length and tension. In the Curtis J. N. 4 it is found inconvenient to take these measurements along the cables themselves. To overcome this difficulty, measure down the front of the right and left struts a certain distance, such as 30 inches, from a definite point on the strut socket fitting, then adjust the diagonal bracing cables until the diagonal distances are equal. Repeat this method on the rear running gear struts.

Another method that can be used is: level the engine beds laterally, then lay a level on the stream line spacer and adjust the diagonal bracing cables until the spacer is level. Lock all turnbuckles and wrap the intersecting points of cables with insulating tape. The pneumatic tires should be tested for pressure and pumped up to about 60 lbs. Take off the weight at the tail of the machine and lift the tail up until the wheels touch the ground. Draw out the 4x4 and bring the tail down until the fuselage is in flying position and is supported by an adjustable trestle under the load points.

ASSEMBLY OF THE WINGS:

The panels are taken out of the packing cases and placed upon their leading edges. Soft padding should be placed under the leading edges to protect the fabric from chafing or tearing. The stagger and flying cables are coiled up and attached to the an-

chors of the wing panel plate fittings. The turnbuckle barrels are attached to the anchors of the lower wing plate fittings. The struts, if not marked for their respective positions, are determined and placed in handy positions for assembling.



Assembly of the Wings and Alignment.

There are various factors which determine the location of the separate struts. The inner wing struts, being thicker, are therefore stronger than the outer wing struts. The rear struts are longer than the front struts. This is due to the lesser depth of the rear wing beams, which naturally follows as a result of the curvature and camber of the wings. The left upper panel and the lower left panel are placed on their leading edges, the lower panel being parallel to the upper panel, and situated at a distance from one another approximately equal to the length of the wing struts. The upper and lower strut socket fittings should be in line. Attach the two front struts first, and then the two rear struts. They are secured by means of bolts and castellated nuts. Screw the nuts on the bolts until they make a snug fit against the sides of the strut socket fittings. Then lock with cotter pins. Attach the stagger cables loosely. They will then serve to hold the panels upright, and release the men who were then holding the panels in position. Uncoil the landing cables from the upper panel and connect to the lower panel, starting the turnbuckle barrel evenly and just covering the left and right hand threads. It is only possible to connect the two outer landing cables since the inner landing cables are attached to the engine section panel. Uncoil the flying cables from the upper panel, and connect to the lower panel. Start the turnbuckle barrels evenly and just engage the barrel about four threads. The flying and the stagger cables will now be loose.

Repeat the assembly of the right wings in a similar manner. The wing masts are now inserted in the sockets. The sockets are welded on the upper wing plates on the top side of the upper panels, directly above the four outer wing struts. No. 1 will be placed on the outer left front, No. 2 on the outer right front, No. 3 in the rear of No. 2 and No. 4 in the rear of No. 1. Connect the turnbuckles of the overhang cables and tighten them until the wing tips from the outer wing struts incline upwards ⅜ of an inch on the front and rear. If the wing masts are not numbered their positions may be determined by the bevels that are cut on the bottoms of the wing masts. The angle of the front wing beam is less than the rear beam owing to the curve of the wing. The shackles and forked end of the turnbuckles on the overhang bracing cables will determine the right and left wing masts. The anchors for the forked turnbuckles are directly above the four inner wing struts. The wing skid sockets are found directly under the outer wing struts.

The right and left wing skids will be denoted by a tag. Insert one end of the wing skid into the socket on the front beam. Align the hole with the holes drilled in the socket. Insert the bolt, then bend the skid and insert the free end into the socket on the rear beam. Put in the bolt and screw on both castellated nuts and lock with cotter pins.

Having assembled the right wings on the right side of the fuselage and the left wings on the left side, they are now ready to assemble on the fuselage.

ATTACHING OF WINGS TO FUSELAGE:

There are several precautions that must be taken before assembling the wings on the fuselage and engine section panel. First apply the lift to the planes under the load points. These points are where the wing struts are connected to the wing beams. Never lift on the trailing edge of the planes as this is merely a structural form designed to take care of the proper finish of the curve and camber of the wing. Take the wing hinge pins out of the hinges on the wings, the large sized cotter pins just being bent enough to prevent the loss of the hinge pin. As the wings are resting on their leading edges, the most convenient lifting position is the balance point on the two front wing struts. Lift the wings up from the ground until the wings have approximately the correct stagger and incidence that the engine section panel has. Attach the female hinges of the lower wing to the male hinges of the fuselage by the wing hinge pins. The longest pin will be at the rear. By attaching the lower wing first, the wings will be supported in the best method to take the weight. This will also allow the weight of the body to be placed upon the sidewalk of the lower wing so that the upper wing hinges may be aligned and the hinge pins inserted.

Care must now be taken that the men holding the bottom end of the wing struts and the wing tip should prevent the wings from being distorted. It can be readily seen that if the rear beam were allowed to hang down unsupported, the joints of the ribs at the wing beams would open, and the fabric would wrinkle and slacken.

The wing hinge pins are placed with the heads pointing outwards. They are cotter pinned through the inner holes, and as an added precaution, the two outer holes on the nose of the hinge pins are wired together by means of flexible wire. The landing cables from the engine section panel are then connected to the anchors situated at the bottom of the inner wing struts. Particular care should be taken that the threads are engaged evenly by the barrel of the turnbuckle. Tighten until the threads are just covered as was done on the outer landing cables.

As the landing cables are used to make the final adjustments of the dihedral angle and also take the load of the wings when the machine is on the ground, by just covering the threads on the inner and the outer landing cables, they will be approximately at their correct length, and the wings will be supported with no distortion in their surfaces. Also the manufacturers make the length of the cables to such close limits that when the threads are covered the dihedral angle in the wings will be within a quarter of an inch of being correct. Uncoil and connect loosely the flying cables in the inner bay. They are fastened to the anchors at the top of the inner wing struts by shackles and clevis pins, and at the other end of the cables by forked turnbuckles to anchors on the lower right and left longerons. The landing cables are now taking the load of the wings. But the leverage exerted by the weight of the wing has a tendency to pull the fuselage over on the side that has the upper and lower wings assembled.

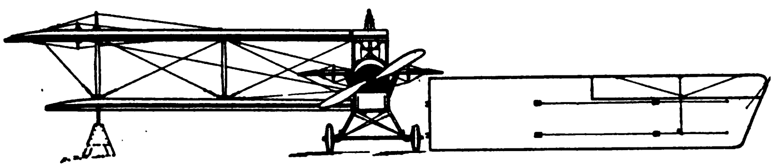


ILLUSTRATION: Place a trestle under the wing skid supporting this wing until the opposite wings have been assembled. Lift the right wings and attach to the engine section panel and fuselage in the same method as used in the connecting of the left wings. Connect the landing and flying cables. The aeroplane will now be perfectly balanced and the supporting trestle under the left wing may be taken out. The aeroplane is now ready for the adjustment of tension on cables and the alignment of the planes.

Lining up of Wings:

A rigger will soon become so accustomed to the angles of adjustments in an aeroplane that he can readily detect any faults by a casual glance. It will therefore be seen that proper lighting is necessary as an aid in lining up the wings of an aeroplane. One should never attempt to line up a machine in a shaded hangar or under artificial light. Wheel the machine into a level position where there are as few shades and shadows as possible. The value of this will be shown when the angle of incidence is being adjusted.

Both the dihedral angle and the angle of incidence are adjusted by means of the landing wires of the planes. Due to the fact that the flying wires increase in tension as the machine leaves the ground, it will be seen that no adjustments can be made by them, other than giving them a tension which will be equalized in flight.

The planes are attached to the lower longerons, and the engine section panel at a definite angle of incidence. Therefore, if the planes are adjusted to the proper dihedral angle the angle of incidence should be taken care of at the same time. In practice it will be found that if the machine is properly constructed, the angle of incidence will be true to within one quarter of an inch, after the dihedral has been adjusted.

To Adjust the Dihedral Angle:

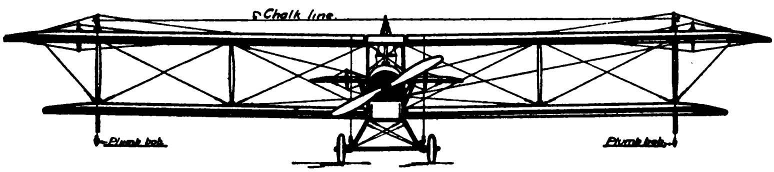
The dihedral angle is adjusted by means of the landing cables. In other words, the planes are raised or lowered in relation to a line drawn parallel with the engine bearers by means of tightening or loosening the landing cables at the turnbuckles. If a plane has not enough dihedral, then it is increased by taking up a few turns with the turnbuckles on the landing cables of that wing. If it has too much, then the angle is decreased by taking off a few turns with the turnbuckles on the landing cables of that wing.

There are two general methods of checking the dihedral angle on the planes:

(1) The Cord Method,

(2) The Dihedral Board Method.

(1) By stretching a cord from the wing masts along the upper surface of the top plane and measuring the vertical dis-



tance from this cord to the plane at definite points along the plane. This method is the one most generally used. The cord should be strong, but not too heavy. An ordinary chalk line answers the purpose very well. Attach the cord securely to the wing mast on one side, carry it across the plane to the wing mast on the opposite side, and draw it taut until there is no sag in the center of the cord; then tie it securely.

The dihedral angle should be checked at two points on each plane. It will be found convenient to use the points of intersection with the engine section panel as one, and the middle wing strut sockets as the other. These points are equidistant on both sides of the center line of the machine; therefore, the right angle distances from the top of the planes to the cord, for the required angle, will be the same on both sides. The degree of the dihedral angle is given, and the right angle distances may be figured out. A simple method of obtaining these is by use of the trigonometrical functions as follows:

The distance $CB =$ the distance $C'B'$
$= AB$ tan. 0
$= AB$ tan. 3°
Supposing $AB = 10$ feet and tan. $3° = .0524$
Then $CB = 10 \times .0524$
Bringing it to inches $= 10 \times .0524 \times 12 = 6\frac{9}{32}''$

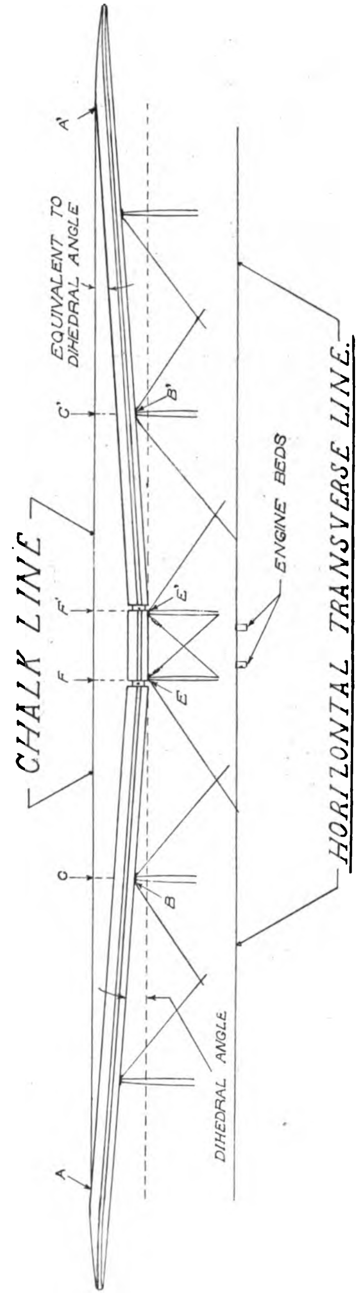
The following is a table showing the dihedral measurements for distances of 10, 15 and 20 feet along the plane and for dihedral angles varying from 1° to 4°.

Degree	Dist.	Meas.	Dist.	Meas.	Dist.	Meas.
1°	10′	$2\frac{3}{32}''$	15′	$3\frac{1}{8}''$	20′	$4\frac{3}{16}''$
2°	10′	$4\frac{3}{16}''$	15′	$6\frac{9}{32}''$	20′	$8\frac{3}{8}''$
3°	10′	$6\frac{9}{32}''$	15′	$9\frac{7}{16}''$	20′	$12\frac{9}{16}''$
4°	10′	$8\frac{3}{8}''$	15′	$12\frac{9}{16}''$	20′	$16\frac{3}{4}''$

In the method so far described the dihedral has been considered along the front beam. The dihedral angle between the planes is the same at the rear as at the front, and although it may be accurate enough, in the adjustments, considering it along the front beams, it is best to check the measurements along the rear beams in a similar manner, as any slight variation would throw the angle of incidence out of adjustment on the planes.

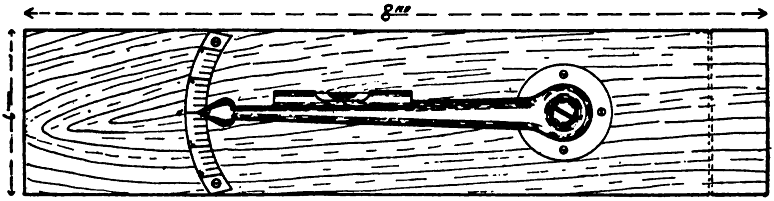
In this method it is not necessary to have the machine in flying position.

From a position some 20 feet in the rear of the machine, sight along the rear cord stretched from wing mast to wing mast, and note that it is parallel throughout with the cord, stretched from the front wing mast on one side to the front wing mast on the opposite side.

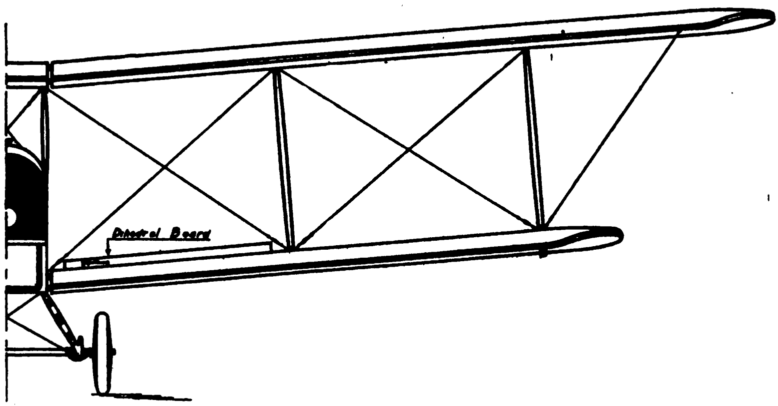

CHALK LINE
HORIZONTAL TRANSVERSE LINE.
ENGINE BEDS
EQUIVALENT TO DIHEDRAL ANGLE
DIHEDRAL ANGLE
A
A'
B
B'
C
C'
E
E'
F
F'

METHOD NO. (2):

A specially designed straight edge board is sometimes used for checking the dihedral angle of a machine. This board is at least long enough to stretch from the outer strut socket fittings to the inner strut socket fittings on the wing. As shown in the illustration it has a cut-out portion graduated in degrees with a movable pointer-arm, on which there is a spirit level.



DIHEDRAL BOARD.
(The pointer to be set to the required amount of degrees. Spirit level indicates when wings are at correct alignment.)



Alignment With Dihedral Board.

ILLUSTRATION: In adjusting the dihedral angle by this method it is necessary to place the machine in flying position, that is the engine bearers must be level. From this it will be seen that if the straight edge is placed along the beam of the wing, and the indicator brought to a level position, it will be registering the degree of the dihedral on the plane.

TO CHECK THE ANGLE OF INCIDENCE:

It was mentioned above that after the dihedral angle had been properly adjusted, the angle of incidence should be found approximately correct. An approximate adjustment is never

good enough for the alignment of an aeroplane so the angle of incidence is checked throughout the entire length of the wings.

As before stated the angle of incidence is fixed where the planes are attached to the lower longerons of the fuselage. This angle may be varied throughout the wing by adjusting the rear landing wires. In other words by raising or lowering the trailing edge of the plane. The specifications contain the degree of incidence to be given to the planes, and the variations of *wash-in* or *wash-out,* if either is applied.

Before attempting to check the angle of incidence, ***place the machine in flying position.*** From the definition (for riggers purposes). The incidence on a plane is the angle the plane makes with the horizontal when the machine is in flying position. It will be seen that when a spirit level is placed against the rear beam of the plane and the bubble brought to the centre, or in other words, the spirit level is a true horizontal line; then the angle it makes with the plane will be the angle of incidence on that plane.

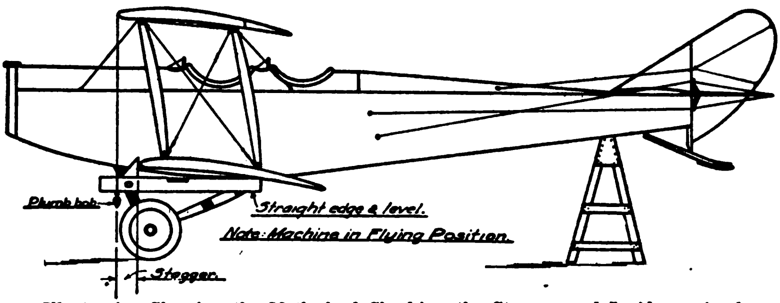


Illustration Showing the Method of Checking the Stagger and Incidence Angle.

If the spirit level is not long enough to reach from the rear beam to the front beam a straight edge is used, and the spirit level placed against its lower edge. The vertical distances from this straight edge to the front beam should be the same throughout the entire length of the plane unless there is a variation in the angle of incidence due to wash-in or wash-out.

Definite points such as the trailing edge of the rear beam and the traiilng edge of the front beam should be taken in checking the angle of incidence. If the vertical distances for this length of chord have not been determined, then they may be figured in a similar manner to the method used in determining the dihedral measurements as shown above. Check the angle of incidence under at least three points on the span of the plane. The incidence on the upper plane is taken care of when the lower plane has been adjusted due to the fact that all struts and fittings are cut to a very fine degree of accuracy for their true lengths and angles.

THE STAGGER:

The flying and stagger wires were left slack while the adjustment for the dihedral and incidence were being made with the landing wires. From the definition—

STAGGER is the projection of the leading edge of one plane over the leading edge of another plane. It will be seen that this measurement can only be taken when the machine is in flying position. The machine was placed in this position before adjusting the angle of incidence so it is only necessary to drop plumb bobs from the leading edge of the upper plane so that they extend below the leading edge of the lower plane and measure the horizontal distance from the plumb line to the leading edge of the lower plane.

The stagger should be checked at two points on each panel. These points are where the planes are attached to the engine-section panel and at the outer struts of the planes. The stagger is increased or decreased by adjusting the stagger wires which run diagonally between the front and rear struts. They should have an equal tension when properly adjusted.

A *final* check to determine if the Dihedral angle is the same on right and left wings should now be made. To do this, measure by means of a steel tape two definite points on the leading edges of the lower wings. These distances are to be taken from where the wings are attached to the fuselage. The corner of each lower wing is to be the starting point for the distances taken.

In the exact centre of the engine section panel, place a small nail. The ring of the steel tape is now put over the nail and the distance taken from the point marked A to the point B as shown in the illustration. This measurement should *coincide* with the distance A to D.

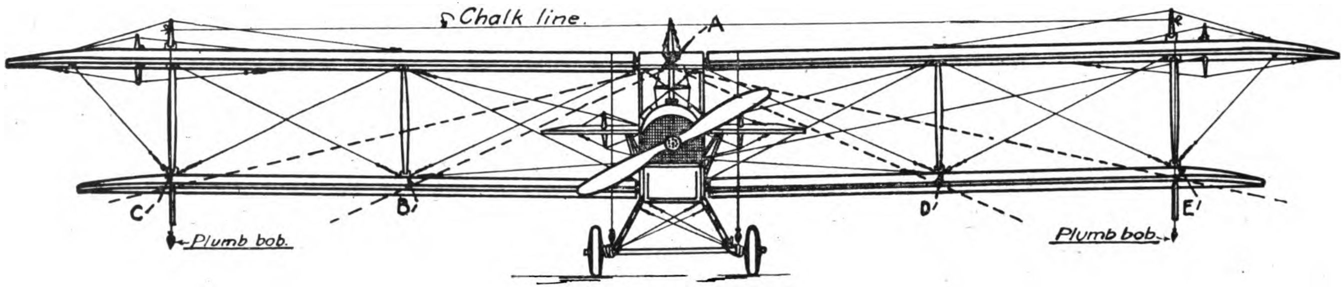
These distances, being proved correct, check distances A to C and A to E.

The machine is now properly aligned. Before leaving, give it a general survey by eye. See that all struts are parallel where they are designed to be so and that there are no bows in the struts or beams. Make sure that all struts are stream-lined. Have all the turnbuckles properly locked.

ADJUSTING THE AILERONS:

Before proceeding to align the wings, it will be noticed that the ailerons will be hanging down unsupported, and to avoid the placing of any unnatural strains on the ailerons or where they are attached to the rear wing beams, it will be necessary to connect the "compensating" or "balance cable."

For the adjustments that will have to be made from time to time, owing to the stretching of the cable, an eye turnbuckle is used, which joins the right and left halves of the cable together.



Final Check for the Dihedral Angle.

It will come in exactly the center of the engine section panel, and just above the front wing beams. Shackles and clevis pins locked with cotter pins secure the ends of the cable to the aileron control posts. As the top wing of an aeroplane is at some considerable distance from the ground, it will be necessary to use a step ladder. Place the step ladder at the trailing edge and just opposite the aileron control post. Uncoil the cable and attach the shackle by inserting a clevis pin through the two holes in the shackle and the hole in the aileron control post. Lock the clevis pin with a ¾"x⅟16" cotter pin. Remove the step ladder to the opposite wing and repeat this operation.

Directly in front of each aileron control post will be seen a ball bearing pulley attached to the front wing beams by "U" bolts. These pulleys are very necessary as the compensating cable makes a turn of 90 degrees at each end of the wings, and is connected in the center by an eye turnbuckle. Align the two pulleys with the cable, noting that the cables seat properly in the aluminum sheaves of the pulleys, and that the pulleys are in correct alignment for the right angle turn. The ailerons should be held up about 2 inches above their neutral position on each side of the wings, in order to make it easier for the rigger who will have to connect the turnbuckle in the center. This takes the weight of the ailerons and allows both hands to be used on the turnbuckle. Connect the barrel of the turnbuckle on the shanks, engaging their respective threads evenly; tighten until the threads are *covered*. The men holding the ailerons can now allow the cable to take the weight. The ailerons will be in perfect balance, and if the measurements on the cable are correct for length, and the right aielron be placed in its neutral position, the left aileron should be seen in exactly the same neutral position. If the ailerons are seen to be below the trailing edge of the wings, they can be brought up to stream-line with the wings by tightening the turnbuckle. To prevent the compensating cable from blowing back when the aeroplane is in flight, a fair lead is used. This secures the cable and holds the cable down to the front wing beam. The aileron control cables are now attached. These cables are used to control the ailerons and the lateral movements of the aeroplane, such as the banking of the machine in right or left hand turns, or to control the extra pressure that is often exerted on either of the wings by wind gusts that throw the aeroplane wings up or down. They are used to bring the wings back into their normal position.

To connect the control cables, uncoil the cables and attach by the shackles to the lower aileron control posts in exactly the same method as followed in the connecting of the compensating cable to the upper control posts on the top of the wings. The lower ends of the "U" bolts holding the pulleys for the compensating cable on the top of the plane, hold the ball bearing pulleys

for the aileron control cables beneath the plane. This pulley acts as a guide for the turn in the aileron control cables. Be sure that these pulleys are correctly aligned to give the cable the proper lead, and that the control cables do not foul any of the stagger cables. Now connect the lower end of the cables by the turnbuckles to the cables that will be noted coming out of the rawhide protections sewn on the linen cover of the fuselage. Engage the threads evenly and tighten until the threads are covered by the barrels of the turnbuckles. Before making the final adjustments to the ailerons, the rigger should sit in the rear seat of the aeroplane. By turning the aileron control wheel to the right, the left aileron will come down, and as the ailerons are perfectly balanced, the right aileron will automatically move up.

The precautions that are taken to prevent the control cables from jumping the pulleys by this movement are as follows: The aileron control wheel in the rear seat and the dual control wheel in the front seat positively work together, by an endless cable. To minimize the friction and to give free movement to the cable, ball bearing pulleys are used. The slack in this cable is taken up by turnbuckles on each side. The control wheels will be connected up in the factory, but an inspection should be made for the tension on the cable. There must be no perceptible play in the cable, but it should not be too tight as this would cause the control wheels to work stiffly. Adjust the turnbuckles for tension and the necessary free movement of the control wheels, then lock the turnbuckles.

The final adjustment on the control cable can now be made and experienced aviators are unanimous in their opinion that a sensitive and a more positive control of the ailerons is obtained by a slight droop in both ailerons. A droop in each aileron of 3/8 of an inch is considered ample and this desired effect can be derived by making adjustments on the turnbuckle of the compensating cable and the turnbuckles on each control cable.

It will be noticed that the eye turnbuckle on the compensating cable was tightened until both ailerons were in the "neutral position." By taking up the slack and applying a little tension on the control cables, the ailerons will be drawn down. This will give about the correct droop.

Before locking the turnbuckles try the aileron control wheels. Be sure that they move freely and that there is no play in the control cables. The aeroplane mechanic should try to excell in the adjustment of the controls since no better test of his ability as a rigger could be given than this, and his workmanship will be soon recognized and commented upon. He will also have the satisfaction of having a job well done.

INSPECTION AND THE PREPARATION OF THE ENGINE BEFORE FLIGHTS.

Filling of the Radiator:

First put a wrench on the radiator drain plugs to determine if they are tight, unscrew the radiator filler cap and put in the required amount of *clean water* through a funnel with a screen strainer in it.

A close inspection of all water lines for water leaks should now be made. If any leaks should be found, tighten the machine screws in the rubber hose connections until the water leak stops. On the lowest point of the water jacketed intake manifold will be found a drain cock. Turn the tap and allow some water to come through. This will eliminate any chance of having an air lock in the water connections or the water jackets. The radiator should never be filled to the top. The water should be seen from the top of the radiator to be four inches down; if not, sufficient water can be drained out by the drain cock mentioned previously. The reason for having the radiator only seven-eighths full is, owing to the expansion of the water through heat, the excess water is sprayed out of the vent tube in the radiator cap and overflow tube, and being blown back seriously inconveniences the pilot. Screw the radiator cap on, and be sure it is *on tight.*

Filling the Gasoline Tank:

First ascertain that the valve for controlling the gasoline from the tank to the carburetor is closed. This valve is opened or closed from the pilot's seat. Try a wrench on the gasoline drain plug and all connections on the gasoline feed line from the tank to the carburetor. Remove, by unscrewing, the gasoline filler cap on the top of the tank. Put about two gallons of gasoline in the tank using a chamois leather in the funnel for a strainer. A close inspection of the tank and all the connections on the bottom of the tank should now be made. Any leaks showing should be made gasoline tight. The drain plug should be pulled up tight on a *gasket.* Open the gasoline control valve allowing the gasoline to flow down the feed line and filling the float bowl of the carburetor.

For any leaks showing on the hose connections, tighten the lock nut until the leaks stop. The feed nut connecting the fuel line to the float bowl of the carburetor must be screwed up tightly on a fibre gasket, ensuring a perfect fit. After making sure that there are no leaks the gasoline still required in the tank may be put in through the funnel with the chamois leather strainer in it. Extreme care must be taken that gasoline does not spill over on the *magneto, engine* or the *sides* of the *fuselage.* Remove the funnel and screw the gasoline filler cap on firmly.

PUTTING IN ENGINE OIL:

The internal lubricating oil is put in through the oil breather situated on the propeller end of the engine. It will be necessary to remove the engine cover to do this. The engine cover is secured by leather straps, and buckles to the side cowls. Detach the buckles and lift the engine cover. As engine oil is always cheaper than bearings, the very best oil should be used in these high speed engines. The engine manufacturers usually recommend the kind of oil that is best suited to the engine. In the case of the Curtiss 0 X 5 as used in the J. N. 4 training machine, Vacuum A for winter use and Vacuum B for summer. A proportion of ¾ Vacuum B and ¼ caster oil in very hot weather has given good results.

It will be noted that a greater proportion of mineral oil than of vegetable oil (castor oil) is used. Vegetable oil has a higher flash point than mineral oil, but when subjected to a high temperature it becomes acid in its action and this acidity would work upon the metal parts of the engine, resulting in the pitting of the cylinder walls. So a greater proportion of mineral oil is used.

Try a wrench on the oil drain plug in the bottom of the crank case and all of the oil connections, making sure that they are tight. The capacity for oil in the 0 X 5 is three gallons, and no more than *three gallons* should be put in. The measure used to convey the oil to the engine should always be kept scrupulously clean. To clean, use gasoline and fresh waste. All funnels and measures should be put away after use, in a place free from sand and dust. Put the required amount of oil in the oil breather through the funnel. This funnel should have a screen strainer of not less than thirty-two meshes to the square inch.

Remove the funnel and measure and replace the cover of the oil breather. It is necessary after every ten to twelve hours of flying to change the engine oil. To do this, unscrew the oil drain plug and drain out the dirty oil. Replace the drain plug and put in about a gallon of kerosene through the oil breather. Examine the magneto switch and see that the switch registers "OFF." Spin the propeller. This will put the kerosene in circulation by means of the oil pump. By removing the spark plugs, the propeller can be spun more rapidly and easier. Remove the drain plug and allow the kerosene to drain. Kerosene can also be squirted up through the drain plug opening.

An excellent squirt-gun can be made from one of the fire extinguishers, usually carried on an aeroplane. A copper tube soldered to the end of the improvised squirt gun can be bent to any suitable shape.

Replace the drain plug and give it a final tightening with a wrench. Put in the required three gallons of oil; then spin the propeller to insure that the bearings are lubricated with the clean oil.

Assembly of the Exhaust Ports and Manifolds:

To cut down the head resistance to a minimum, it will be noted in the tractor type of aeroplane that the engine is installed with all its connections; radiator and its water lines in a very compact form and the cylinder heads come in close proximity to the upper longerons. To prevent the longerons from being burnt by the hot gases, exhaust ports and manifolds are used to carry away the burnt gases.

As mentioned previously, these very important parts of the engine are contained in a box fastened to the bottom of the fuselage packing case. For the purpose of designating left and right, and front and rear, everything is taken as viewed from the pilot's seat. The cylinder on the left side nearest to the pilot is known as No. 1 and the magneto setting and valve timing is taken on this cylinder by means of the piston travel. The remaining three cylinders on the left side will be numbered 3, 5 and 7 and the cylinders on the right side will be numbered 2, 4, 6 and 8 respectively.

The exhaust ports are numbered, the number being found on the bevelled end of the steel tubing forming the exhaust port. The exhaust ports are secured to the engine by means of hexagon head bolts running through a suitable flanged casting welded on the steel tubing and then screwed through two holes drilled and tapped into the cylinder heads. To lock the bolts securely, lock washers are used. Select No. 1 exhaust port; place a lock washer on each of the two bolts. Insert the two bolts through the flange, place on the ends of these bolts the gasket composed of asbestos and sheet copper. Engage both bolts in the holes provided on No. 1 cylinder and screw up. By engaging both bolts at one time and screwing up with the fingers as far as possible all chances of stripping the threads are eliminated. Follow this method on all of the other cylinders.

The two warm air stoves are stream lined sheet steel forms used with the flexible tubes to conduct warm air to the air intake on the carburetor, and are usually used for winter work only. These stoves slide over the exhaust ports and are secured to the ports by means of two clips welded on each stove. These clips are drilled for a $\frac{3}{16}''$ round head machine screw and correspond with the holes drilled in numbers 1, 7, 2 and 8 exhaust ports. Determine the right and left stoves. Take the right hand one and align the four holes in the stoves with the four exhaust ports, slide the stove on the ports. Secure with two $\frac{3}{16}''$ machine screws and nuts. The threads on the ends of the machine screws are burred over to prevent the plain hexagon nuts from coming off. Repeat on the left hand side of the engine. The bolts securing the exhaust ports should now be tightened up. A handy wrench to do this with is an off-set socket wrench. The spring lock

washers should be squeezed up until they are flat. In the tightening of these bolts none should be missed. If any have been, it can be readily seen that, with the aeroplane in flight, the vibration of the engine would shake the loose bolt out, and the bolt being blown back could seriously injure either the passenger or the pilot. As an added precaution for the protection of the upper longerons, sheet asbestos is tacked on the longerons where there is any danger of an exhaust port coming within an inch of the upper longerons. To complete the assembly of the warm air needed for the carburetor, two flexible tubes remain to be attached. The right hand flexible tube will be longer owing to the four cylinders on that side of the engine being staggered and ahead of the four cylinders on the left side. A tag on one end of the tubes will be marked "carburetor end," the other end is inserted into the warm air stove.

Put the stove end through the hole in the aluminum side cowl and push the end into the tube connection on the stove. Align the holes and secure with a ¼x3 inch hexagon bolt, a castellated nut and cotter pin. The carburetor end of the tube is fastened in a like manner.

After this assembly is completed check up on all the work done on it.

Putting on the Propeller:

A large majority of aviation engines have the propeller mounted directly and held rigidly on the crank shaft, or in other words have a "direct drive." It can be readily seen that the connection known as the propeller hub, used to secure the propeller to the shaft will have to make a perfect fit. Where the hub on the crankshaft of the Curtiss 0x5 is secured, the crankshaft is tapered and the hub positively held from slipping by a key and key way, the key way being machined in the propeller hub and the key on the tapered end of the crankshaft.

The machine work must be very accurately done on both the shaft and the hub. To get this perfect fit, the inside of the hub and the tapered part of the shaft must be *thoroughly cleaned*. To do this, take a piece of clean cheese cloth and damp it with gasoline; carefully clean the shaft and the inside of the hub and pay particular care to the key way in the hub. This work will have to be done well because, for the prevention of rust, all the steel parts of the engine will have been liberally soaked with vaseline, and grit may have stuck to the vaseline. After examining and being satisfied that the hub and shaft are clean, a very thin film of clean engine oil should be put on the shaft. Now slide the propeller on to the crankshaft, tapping the thickest part of the blades with both hands. Swing the propeller around until it

is in the correct position for cranking, feeling when the propeller is in motion for the compression point.

The four compression points are situated at 45 degrees off an imaginary horizontal line drawn through the centre of the crankshaft. If possible the propeller, when in the correct position for cranking, should be directly on the highest point of compression or a little past.

As *"Safety First"* applies to the aeroplane mechanic as much as it does to the pilot, the propeller must be put on correctly. Knowing the propeller to be on correct, it will give the mechanics that have to crank the engine some feeling of security. It can be seen that by not getting sufficient momentum at the start of the cranking movement owing to the propeller being on wrong, a back fire might occur, and under the impulse of this premature explosion, the propeller would be driven backward and possibly draw the mechanic in and cause serious injury to him. If the propeller when tried on, does not come right for this position the hub can be changed. Mark the hub with a pencil to show the way it should be moved ahead or back. Take off the propeller and lay it on a bench with soft pads under the blades. Remove the cotter pins and the 8 castellated nuts from the hexagon head bolts. Drive out the bolts and be careful not to damage the *threads*. Take off the piano wire locking ring securing the large nut in the centre of the hub by means of a screw driver. Unscrew this nut by means of the special socket wrench that is provided for it. Move the hub around one hole ahead or back in the direction required. This will change the location of the key-way in the hub, thereby changing the position of the propeller in relation to the keyed shaft. Turn the propeller over, align the holes properly, grease the bolts and drive them through until the heads of the bolts are up tight on the hub.

Clean the threads for grease and sawdust that will be on them. In addition to castellated nuts, these bolts will have heavy steel lock washers. Put on the lock washers and start the nuts. Now replace the large centre hub nut and tighten until one of the holes in the side of this nut is aligned correctly with one of the four slots machined on the threaded part of the hub. Slide the piano wire locking ring on and press it firmly into place. Now tighten the 8 castellated nuts. Each one must be at the same tension. If this care is not taken the extra tension on some of the nuts will throw the propeller out of alignment by squeezing one side of the hub into the wood. This would have a bad effect on the engine causing *excessive vibration.*

Put the propeller on again, using the same precaution for cleaning as mentioned previously. To drive and hold the propeller on the shaft, a nut is screwed on the end of the crankshaft driving the hub onto the taper. This nut is pulled up with a socket wrench which is used only for this nut. The necessary

leverage for the socket wrench used, is supplied by a steel bar ¾ of an inch by 2 feet. The nut should be pulled up very tight and locked with a piano wire lock ring of smaller radius than the one used on the centre hub nut. Align one of the three holes in the side of the lock nut with one of the four slots in the threaded part of the *crank shaft*. Never back up the nut for alignment. Try another quarter of a revolution of the nut if possible. After the holes are aligned properly, slip on the lock ring and press it firmly into the holes. The end of the lock ring is shaped for this purpose. The tension on the ring holds it in place.

THE CARE OF THE ENGINE.

In direct contrast to the average automobile engine, an aeroplane engine must have constant care and attention. The aeroplane mechanic on his maiden trip in an aeroplane does not pay much attention to the engine, being usually too busy with other things. His thoughts, if they could be read, would be those of doubt as to the pilot's ability to land the aeroplane safely in that small patch of green which looks to him about six inches square, and as to whether or not the pilot really knows what he is doing. But after the mechanic has been up three or four times, a feeling of great respect will come to him for the light but powerful engines which furnish the motive power for aeroplanes. The attention which must be given to the smaller details are very forcibly brought home to him when, for instance, the pilot has just left the ground and a cylinder misses a few explosions. A feeling of relief will come to him when the engine picks up and its steady rhythm sounds again. One of the most important things will be to keep the engine clean and the best time to do this is when the engine is warm after the flights are finished. Some parts of the engine are difficult to get at. These parts can be cleaned with a soft brush and kerosene. The advantages of using kerosene over gasoline for cleaning are: kerosene has some lubricating qualities and does not evaporate so rapidly as the gasolene. Start at the top of the engine and working down flush the dirty oil down. The lower half of the crank case can be wiped with soft clean rags.

After cleaning the engine, all the external moving parts should be well lubricated. The wearing of these moving parts of the engine, would be the result of neglecting the external lubrication. Any oil that has been blown back on the outside of the magneto should be wiped off with a soft rag slightly dampened with gasolene. After about ten hours' flying time, and at the first opportunity lift off the clamp holding down the spark plug terminals in the distributor block. Lift the terminals and remove the distributor block. This will be done to remove the carbon deposit left by the friction of the distributor finger brush

on the distributor block. An ordinary rubber pencil eraser will remove this deposit much cleaner than gasolene. Put back the distributor block. Remove the worn surfaces on the two small carbon brushes of the distributor finger brush with a smooth flat file.

Replace the finger brush and cover. Note where No. 1 terminal starts. The numbers on the terminals will be designated by a ring or rings turned on the insulating material, one ring representing No. 1, two rings for No. 2, and so on. Secure the terminals by the clamp which holds them down. Remove the breaker box cover and examine the platinum contact points. A special wrench for the adjusting of these points goes with the magneto. This wrench will have a thickness gauge attached to the side of it. This gauge should just pass between the platinum points when fully opened.

If the points are seen to be closed when the breaker box cover has been removed, turn the propeller *backwards*. This precaution is taken as the ignition will be "ON" owing to the switch wire terminal being connected to the breaker box. A gap of not less than .016 or over .020 between the points should be allowed. If these adjustments are necessary, make them and be *sure to replace the breaker box cover,* as this is necessary to give control of the ignition by the switch. Quite a number of serious accidents have been caused by this neglect. Replace the breaker box cover so as to prevent these unnecessary accidents. Lock the breaker box with the tempered steel spring.

Valve Clearances and Other Adjustments:

The clearances on the valve tappets should be checked after every twelve hours of flying. The clearances on the Curtiss 0 X 5 as recommend by the makers are:

.010 of an inch on the exhaust }
.010 of an inch on the inlet } when the engine is cold.

A faulty ignition switch is the cause of a great number of accidents while turning the propeller. This danger may be eliminated by removing the ignition wires from the spark plugs. This precaution is made a rule in most flying schools. Turn the propeller "ahead" until the exhaust valve on No. 1 cylinder opens and closes. The intake valve opens immediately after the exhaust valve closes, when the propeller is rotated in the right direction. The exhaust and intake tappets are in their neutral positions when both valves are closed. Select the "feeler" numbered .010 on a thickness gauge. Place it between the tappet and the top of the exhaust valve stem. Slacken the lock nut. Turn the slot in the case hardened set screw with a screw-driver until the set screw touches the gauge. If the engine has had a lot of running, consid-

erable play will be felt in the rocker arm. Be sure to take care of this play when turning down the set screw.

Still holding the set screw with a screw driver, *tighten* the lock nut. Repeat this method on the intake valve. The only difference for adjustment will be that the adjustment is made on the intake push rod. The firing order of the cylinders on the 0 X 5 is 1, 2, 3, 4, 7, 8, 5, 6. The clearances should be checked in this order. In spite of all the precautions taken when straining the gasolene into the gasolene tank, water and dirt will be found in small quantities. The dirt will plug up the small holes in the jets. The consequent missing of the explosions will be the result of the dirt stopping the flow of the gasolene.

On the Zenith type of carburetor the dirt is taken care of by well nuts situated under the four jets. These nuts may be unscrewed and the dirt and water cleaned out. The method to follow in the cleaning of the well nuts will be: Turn off the gasolene by the control wheel situated in the pilot's seat. Remove the wire used to serve as a lock for the four well nuts. The nuts are made of brass, so therefore of comparatively soft material. If available, use either an open end wrench or a socket wrench. Adjustable wrenches, if not properly used, will often slip and damage the hexagon sides of the nuts. Unscrew the nuts and clean thoroughly. Turn on the gasolene control and allow the gasolene to flow for a second or two. This will flush out any dirt still remaining inside. Before replacing the nuts, be sure that the fibre gasket is on each nut. Screw on the nuts. Tighten and lock them with a piece of *new* wire.

The cleaning of the well nuts should be done every morning before flights. The spark plugs should be taken out and cleaned at frequent intervals. The time to do this will be when the weather conditions are impossible for flying. It is frequently necessary to change spark plugs due to the collection of oil on the spark plug terminals. When the weather is favorable, as much flying time as possible is put in and a healthy spirit of competition is encountered between the different "flights." The spare time should be spent in adjusting and cleaning the engine.

When taking out the spark plugs, use a socket wrench. Only use an open end wrench in an emergency. An open end wrench will frequently slip, especially where the spark plug is placed in an inconvenient position. This is liable to result in cracking the porcelain of the plug. If the plugs can be taken apart, clean the electrodes with fine emery cloth. Then clean them with gasolene. The gap of the spark plug points can be set to the thickness of the gauge used on the contact breaker points. After cleaning, replace the plugs making them compression proof by screwing them down tightly on the copper gaskets.

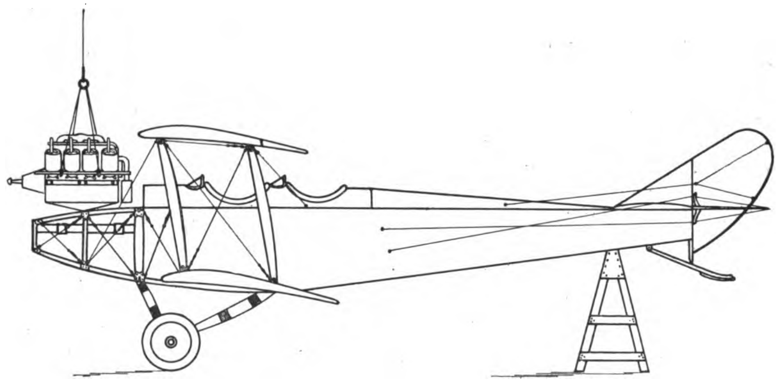
The spark plug wires should be well insulated and just long enough to reach their respective spark plugs. Do not allow any

slack in the wires, for the reason that the wire may get under some moving part and being partly cut through will short circuit the plug.

INSTALLING THE ENGINE.

Water-cooled aero engines require complete overhauling after fifty hours' duty, and special workshops and mechanics take care of this essential work. To move the engines they are temporarily placed in trucks of special construction. Wheel the truck under the chain falls used to hoist the engine into the fuselage. To attach the engine to the chain falls, slings of steel cable ⅜ of an inch in diameter are employed. On some engines special eye bolts are provided to take the hooks of the sling. Unfortunately, on Curtiss engines this is not so. The safest method to lift this type of engine is to place a steel rod two feet six inches long with a diameter of one-half an inch under the water jackets of the cylinders on each side of the engine.

Attach the hooks of the sling as shown in the illustration No. 12. On the Curtiss engines, as used in the J. N. 4, it will



Installing the Engine.

be necessary to put the rubber hose connection on the inlet pipe of the water pump before installing. Hoist the engine by the chain falls high enough to allow the machine to be wheeled underneath. Lower the engine carefully into place, the chain falls still taking the weight. Contrary to the usual practice, the heads of the engine bolts will be down. Align the bolts with the holes in the lugs of the engine and drive up the bolts. Attach a weight to the tail of the machine. The engine beds can now safely take the weight of the engine. Detach the sling and remove the steel rods. The engine lugs should now be seen to seat closely on the engine beds. If two of the corner lugs ride, shim up the opposite corners with sheet cop-

per. It can be readily seen that if the engine beds are not level and the lugs being tightened down a distortion in the crank-case would follow. Place steel washers on the bolts, and then the castellated nuts.

Following the excellent engineering practice, screw down the castellated nuts on the opposite corners. The connecting and assembling of the installation, still to be done, should be taken in the following order:

Radiator

(The two top water connections, connecting water jacket of the cylinders to the radiator.)

Carburetor

Gasoline line, connecting gasoline tank to the carburetor.

Throttle connections, connecting butterfly valve to throttle levers

Lower water line, connecting radiator to water pump.

The two water lines from the water pump to the water jacket intake manifold

Oil pressure line

Ignition switch wire

Fill the radiator up with water. The engine is now in an accessible position. Any leak showing can be remedied.

The Aluminum side cowls. Right and left

Exhaust ports

Warm air stoves and flexible tubes

Propeller

Drift cables

Engine oil

Gasoline

Engine cover

WATER LEAKS.

Any water leaks that develop in the radiator, water connections or around the water pump should be fixed immediately. In the case of a leak on the top water connections the water will blow back on the pilot's goggles and interfere with his vision. A leak on the rubber hose connections of the circulating pump is often the cause of water getting in the float bowl of the carburetor. The water will get in through the needle valve guide in the float bowl cover. A dust and water protector is provided for the float bowl.

To flood the carburetor the needle valve is raised and the dust cap must be unscrewed. Never neglect to replace this cap. It will be necessary at times to tighten the packing gland nuts on the water pump owing to a water leak. These two nuts are situated on each side of the pump. A left hand thread on one nut and a right hand thread on the other nut offset the tendency of the crankshaft's rotation to slacken the nuts.

Before tightening the packing gland nuts, note the rotation of the propeller. This will determine the location of the right and left threads. A special wrench will come with the engine tools for these nuts.

RADIATOR LEAKS:

Owing to bad landings a leak will often start in the radiator. Mark the leak with an indelible pencil. Drain the water; remove the propeller; the inlet water connections and the outlet connection. The castellated nuts holding the radiator to the nose plate of the fuselage are unscrewed, also the bolts securing the aluminum side cowls to the radiator. Tilt the radiator forward about 45 degrees and lift it carefully from the machine. Lay the radiator on soft pads. A flux of muriatic acid cut with zinc will clean the dirt and grease from the surface of the metal to be soldered. When soldering do not hold the soldering iron too long on the part being soldered. This would cause the thin honey comb sections to melt, thereby causing another leak. Test the radiator for leaks by the following method before placing it on the machine. Solder an ordinary air valve to the vent tube on the radiator cap. Insert a wood plug in each of the pipe connections and the overflow pipe. These plugs must be water-tight. Fill the radiator with water and screw on the radiator cap. Attach an ordinary tire pump to the valve on the radiator cap. A few strokes of the pump will be found sufficient to produce a pressure of about two pounds per square inch. This pressure will force the water through any holes that may be present. If there are any leaks, they should be marked and repaired, as shown above. When it is possible, the small radiator leaks should be repaired on the machine, as removing the radiator takes considerable time.

The vibration of the engine will frequently open the joints on the inlet or outlet pipes. It is unnecessary to take the radiator off in repairing such a leak. Place the propeller in a horizontal position. Raise the tail of the machine until the radiator is nearly horizontal. Rest the end of the crankshaft of the machine on a pad. It will then be possible to solder the leak. As this is not the normal position for the aeroplane to be in, no time should be lost in making the repairs.

CARE OF THE PROPELLER.

After flying has finished for the day and the aeroplane returned to the hangar, the propeller should be cleaned thoroughly. A soft cloth dampened with gasoline will remove the oil. Sand or dirt being picked up by the propeller may have adhered to the oil on the highly finished surfaces of the propeller. When cleaning, do not allow this grit to scrub the

finish of the propeller. Any dents or abrasions on the blades should be revarnished. Badly warped or broken propellers should have the hubs taken out and put into new propellers.

Spare propellers must be carefully stored in a place with an even temperature at all times, and neither too dry nor too damp. They should be suspended on horizontal pegs, allowing the free circulation of air around the blades.

ALIGNMENT OF PROPELLERS.

A pilot may report that while in the air excessive vibration was felt in the engine. This may have been due to a warped blade of the propeller. If the engine was allowed to run with a warped propeller for any length of time, a serious effect on the crankshaft and engine would be the result. If the propeller is suspected of this excessive vibration, it can be checked for alignment in the following manner: Bring the machine into flying position and chock the wheels. Turn the propeller until perpendicular. Place a block of wood just touching the propeller tip. Turn the propeller half a revolution. A comparison of the propeller tips can now be made with the fixed object. If a variation of 5/32 of an inch be found, replace with a new propeller.

A check to determine if the blades are of equal length can also be made by comparing each blade with a fixed object. This is the only fault in a propeller that can be remedied. It will be necessary to remove the propeller. The tip of the blade found to be the longest should be shaped down by an expert woodworker. Do not neglect the revarnishing of the surface, after the tip of the blade has been pared down.

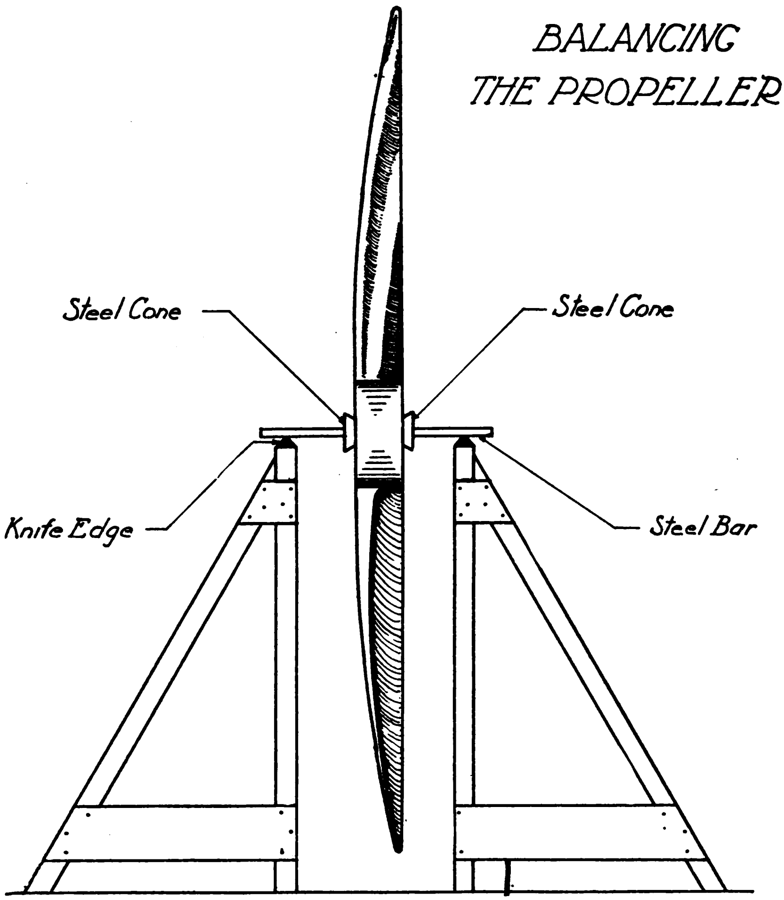
BALANCING OF THE PROPELLER.

A propeller must be perfectly balanced, for at the high speed of its rotation any out of balance will cause excessive vibration to the engine. Before balancing, it is the usual practice to remove the propeller hub. It will not be necessary to do this if the following method is used. If available, secure a *scrapped* crankshaft. With the crankshaft securely held in a vise, saw the shaft in two at a point between the thrust bearing and the first bearing. Secure thrust bearing firmly at a distance of five feet from the ground. The sawn off section of the crankshaft will now be in the form of a ball bearing spindle and can be spun freely. Slide the propeller on the tapered shaft. The propeller should now stand in any position that it may be placed. If one of the blades is proved to be heavier than the other, one or more coats of varnish can be applied to the lighter blade, thereby bringing the blades to perfect equilibrium.

The following method can be employed to balance a propeller not being hubbed. The following equipment will be necessary: Two steel cones machined with a suitable taper that fit the large boss hole of the propeller snugly. Drill a hole with a diameter of one and one-thirty-second inches in the exact center of each cone.

One round steel bar two feet long and one inch in diameter.

Two trestles five feet high.



Level the trestles and nail them down to the floor with a space of eighteen inches between them. Place a piece of triangular steel on the top of each trestle. Insert the steel rod into the boss hole of the propeller. Slide the cones on the ends of the rod and tap the cones until they grip evenly on both

sides of the propeller. Place the ends of the steel bar on the triangular pieces of steel as shown in the illustration. Balance the propeller by the application of varnish on the lighter blade, and be sure that the room when balancing the propeller is *free from all disturbing* air currents.

TO CHECK THE PITCH OF A PROPELLER.

As the steel table of a drill press is usually adjustable four ways, it makes an ideal bench to use. Adjust the table with a spirit level until it is level every way. Lay the propeller down with the pitch side facing upward. Fit a wooden plug in the large boss hole and in the exact center of the plug drive a nail, allowing the nail to project up about an inch. Place the ring of a steel tape over the nail and starting with a radius of 15 inches mark the leading and trailing edges of both blades very accurately. Add five inches to the first measurement, and mark in a similar manner. Continue until both blades will be layed out in five-inch spaces extending to the tips. Check the table for level again and clamp the propeller down. Starting at the fifteen-inch mark, place a bevel protractor on the point marked on the leading and trailing edge. Lift the spirit level attachment of the protractor until perfectly level. Note the degrees indicated on the protractor and record on paper. Continue in this manner at the points layed off along the edges of this blade.

Take the measurements of the pitch angles on the opposite blade and compare these with the first readings. A propeller is considered defective if a variation of ten minutes is found in the pitch angle.

TO TIE A MACHINE DOWN IN A FIELD, WHEN IT IS TO BE LEFT OUT OVER NIGHT.

Supposing a machine has made a forced landing away from the aerodrome, due to engine failure or the pilot having lost his way just before dark. It will be necessary to take certain precautions to prevent injury to the machine over night. The first step taken is to bring the machine to the most sheltered place in the field. The lee side of a hedge or building will offer a certain protection against the wind and rain. Place the machine so that it heads directly in the eye of the wind. Place chocks in front of the wheels. Attach a rope to each outer front wing strut and lash each rope securely to a peg driven in the ground. Secure the tail in a similar manner, by fastening a rope to the tail-skid post. Lash the controls in their neutral positions. Cover the engine with a tarpaulin or some waterproof material. Do the same to the propeller. Drain the water from the radiator if there is any danger of frost. Place a guard on the machine to prevent the people,

who are tempted by curiosity, from stepping on the machine. The ordinary man in the crowd would just as soon put his feet through the planes as on the beams. It will be found that some people have a great desire to have their names and addresses on the fabric of the machine. This practice should not be encouraged. If there are any cows in the field, it will be found necessary to drive them away from the machine as the fabric appeals to their appetities.

TO START A PROPELLER WITHOUT AID.

There are occasions when it is impossible to procure help in starting the engine. This may be overcome by using a few precautions. The pilot should first turn the machine into the wind and see that there is plenty of room to turn around in the field if such a move is necessary. Place a block of wood in front of the wheels. Secure the control column back towards the pilot's seat. The control column may be held back by locking the safety belt around it. This will raise the elevators and tend to hold the tail of the machine on the ground when the engine has been started.

Inspect the magneto wiring and see that the ground wire is properly attached and that the breaker box is on. Place the switch in the "OFF" position. Open the throttle about half way and close the air. This will allow a rich mixture of gas to be sucked into the cylinders. Turn the propeller rapidly through a few revolutions, then close the throttle and open the air intake tube.

Start the engine in the usual way and be ready to take immediate action if anything goes wrong. When the engine is turning over at its lowest rate remove the block of wood from in front of the wheels and climb into the pilot's seat. Release the control column and carry on in the usual manner. The above method may be used where the machine is equipped with a stationary engine. In the case of a rotary engine the practice of starting the motor by one's self is more complicated. It is sometimes possible to adjust the throttle by the fine adjustment needle, but this operation should never be put in practice except where unconditional circumstances warrant it.

CAUTIONS FOR AVIATION MECHANICS.

1. Never attempt to start a new engine without having a fire extinguisher handy.

2. When making engine adjustments and the necessity of turning the propeller, be sure of the "ignition" by disconnecting spark plug wires.

3. Before starting an engine be sure the wheels are blocked and the tail of the machine turned, so that the dust blown back by the propeller is not blown back into the hangars or workshops.

4. Be sure that the engine will throttle down without stopping at 400 R. P. M.

5. Before allowing a machine to leave the ground, warn the pilot if any other machines are on the point of "landing," or "taking off."

6. When replacing a defective spark plug, do not leave tools or the defective plug on the engine cover.

7. After making minor repairs, be sure to check up the tools used.

8. Never crank the engine with tools in the pockets of overalls.

9. Pliers are not used by good mechanics to tighten Hexagon nuts or turnbuckles.

10. If the mechanic is called away while doing repairs, be sure to attach a card in some prominent place on the machine saying (machine not *serviceable*).

11. When mechanics are required to walk down the field to make minor adjustments on an aeroplane, having had a forced landing, be sure to keep a sharp look-out for other machines landing or getting off.

12. After flights, be sure the gasoline is turned off and the switch registers OFF.

THE GENERAL INSPECTION OF AN AEROPLANE.

When a new or a strange machine is taken over it should be given a general inspection before reported ready for flying. Starting at the running gear, it should be noticed that all wires are of the proper tension, and that their respective turnbuckles and shackles are locked. The nuts on the strut socket fittings and on the plate fittings should be properly locked with cotter pins. The hubs of the wheels should be well greased, and the axle collars securely fastened with hexagon bolts and castellated nuts. The tires should be inflated to sixty pounds pressure.

The stream-line covering on the tangent wire wheels should be well doped and securely held on. Remove the inspection cover on the fuselage. See that all diagonal bracing wires are at the proper tension and that they are bound with insulating tape where they cross one another. All nuts and turnbuckles should be properly locked. Pay special attention to the control wires seeing

that they run in a straight line and do not foul with any of the internal bracing wires. Open the doors hinged to the engine side cowls and examine all the internal bracing wires. Make sure that the engine bearer bolts are well trued up and that their respective nuts are properly locked. All hose connections and feed pipes should make a tight joint. See that the radiator and gasoline tanks are properly filled and that there is plenty of oil in the sump of the engine. Examine all the ignition wires and terminals, paying special attention to the ground wire from the magneto. Replace the inspection cover.

THE TAIL UNIT.

Examine the lock-nuts on the "U" bolts for the horizontal stabilizer and the vertical stabilizer. See that all the hinge pins for the rudder and elevators are locked with cotter pins. The diagonal bracing wires should be tested for tension and the turnbuckles should be properly locked. See that the shackles on the control cables are secured with cotter pins through the clevis pins.

THE ENGINE SECTION.

All struts should bear evenly on their bases. The nuts on the hexagon bolts of the strut socket fittings should be well drawn up and secured with cotter pins. All diagonal bracing wires should be of equal tension, and their respective turnbuckles should be locked.

THE MAIN PLANES.

First note that all the struts are placed in a stream line position. Have them parallel where they are designed to be so. The pins on the strut socket fittings should be locked with cotter pins, and all should be placed with the heads pointing towards the front of the machine or with the nuts on the side so the pilot may inspect them from the pilot's seat. Test the landing and flying wires for tension. See that the turnbuckles are locked.

CONTROLS.

All control wires should be properly greased, especially where they run through the fair leads and around the pulleys. They should move freely and have just the right amount of play as previously described in the adjustment of the same.

THE CARE AND INSPECTION OF AN AEROPLANE BEFORE AND AFTER FLIGHT.

When it is possible a rigger should watch the landing made on the machine. If it has been subjected to any undue strains,

he will be able to form a fair idea of where to look for weakened or broken parts. After a heavy landing, the running gear should be well gone over. First test the wires for tension. If they are right there is little danger of the remaining parts being out of true. It is well to inspect the strut socket fittings as they are liable to have been injured. If the fabric on the fuselage is wrinkled remove the inspection cover from the fuselage and test the wires for tension. Inspect the longerons and the strut socket fittings. Test the controls. See that they move freely and that the control cables have not been stretched. Inspect the control cables, seeing that they are not frayed. Frays may readily be detected by running the hand along the cables. Any loose or broken strands will make themselves known. Wipe the oil from the propeller and inspect it for openings in the laminations or splinters. If the propeller tips have suffered from running through long grass or over cinder grounds, have the propeller removed and a new one placed on the machine. See that the fuel tanks have not been loosened.

If the machine is to be left on the field, place it so that it is headed directly in the eye of the wind. This will prevent it from being tilted over sideways and will also keep the movable controlling surfaces from being injured by flapping in the wind. Some machines are fitted with small rods or cables in the pilot's seat, for the purpose of lashing the controls in their neutral positions. This will prevent any damage being done by a change of wind. It is well to place chocks under the wheels as these will be needed before starting the motor for the next flight. When there is a strong wind blowing, the wing tips should be held down. This may be done by fastening a rope to the outer struts and lashing it to a peg in the ground. Most machines are equipped with a ring on each front wing tip skid socket. These rings are used for attaching a weight, such as a pail of sand, which will prevent the wind from raising or lowering the wings.

Before a machine goes on a flight, it should be given a general inspection. If the machine is in constant use the inspection need not be very thorough, as any defects will have been noted by the pilot during the previous flight. Give the machine a general inspection by eye. *Test the diagonal bracing wires* in the center section, as these are the first to become strained during flight. Try the controls. See that they move freely and that they have the proper tension; also make sure that the fair leads and pulleys are properly greased and that the control cables are not frayed; have the radiator properly filled and be sure that there is plenty of oil and gasoline for the flight to be taken; set the altimeter at zero, as the pilot is liable to forget this before "TAKING OFF." This might result in a misjudged landing

due to the altimeter not registering the true height above the landing field.

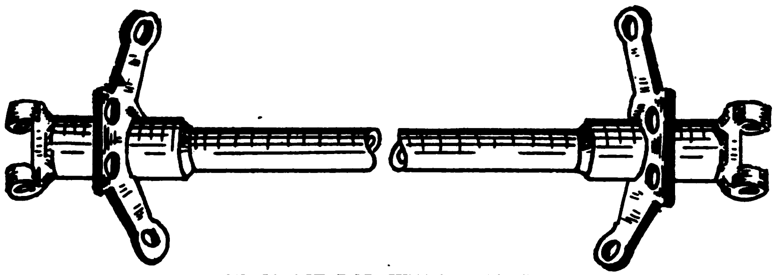
Before the machine is put away for the night, it should be properly wiped and all exposed wires should be given a coat of hard grease. Care should be taken that no oil or grease is left on the fabric as this will deteriorate it faster than anything else. If it is frosty weather and the hangar is not heated, care should be taken to have the radiator properly drained.

AEROPLANE CONSTRUCTION AND MATERIALS

WING BEAMS.

The material largely used in the manufacture of wing beams is clean grained Silver Spruce. It can be procured in suitable lengths and is easily worked. Its texture is very strong and elastic; also it has the added advantage of being light in weight. The wing beams are under a strain of direct compression; spruce with its great compressive strength makes an ideal material when used for this purpose.

The spruce being wanted in such large quantities and lengths, the wing beams have been manufactured by laminating pieces of



WING TIE ROD WITH HINGES.

hardwood and under exhaustive tests, these beams have proved very satisfactory. To further lighten a spruce wing beam and still retain its maximum strength, portions of the wing beam are machined out, forming the shape of a steel girder. These hollowed out portions also help in the attaching of the ribs. If it is necessary to drill a hole through a beam, the greatest care must be taken. Before drilling a hole have someone sight the drill in front and the side for alignment.

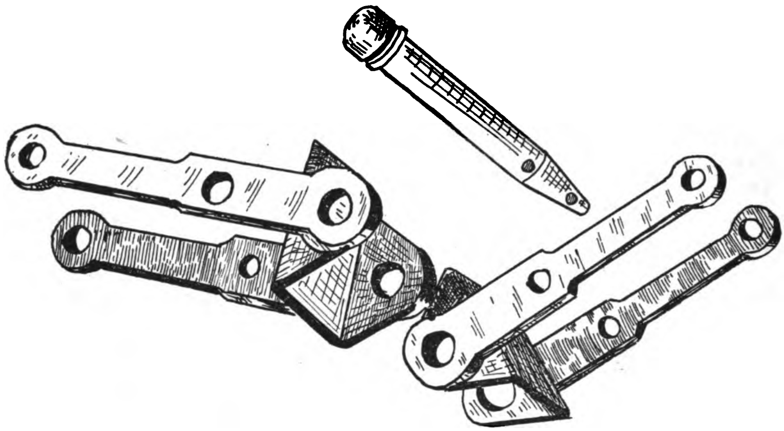
To avoid costly mistakes, make sure before drilling that the drill is the correct size. The beams are given several coats of clear shellac varnish to resist moisture and to aid the waterproofing of glued joints.

WING RIBS.

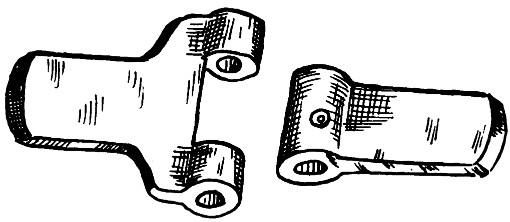
The material used for ribs in the majority of aeroplane wings are spruce for lightened ribs and white ash for compression ribs. The purpose of the ribs is to space the wing beams and give to the fabric the form of the wing. Many of the ribs can be con-

siderably lightened for weight by lightening holes of correct proportion. These ribs are known as "Lightened Ribs."

Diagonal braces of piano wire are connected to the wing beams. They hold the wings rigid and prevent them from telescoping when the machine is in flight. It can be seen that when tension



Male and Female Hinges, also Wing Hinge Pin.



Male and Female Hinge.

is applied on these bracing wires by means of the turnbuckles a rib of greater strength must be used. These ribs are solid and designated as "compression ribs." Cap strips of spruce are used to stiffen and connect the nose, center, and tail ribs together. The cap strips are secured to the top and bottom ribs by small brass *flat head screws.*

THIMBLES.

Used for the protection of the loops of cables. Made of sheet steel, and the size to be used may be determined by taking the diameter of cable and adding $1/32$ of an inch. The size of the thimble will be found stamped on each thimble.

STEEL WASHERS.

Two kinds of steel washers will be found in the assembly of the machine:

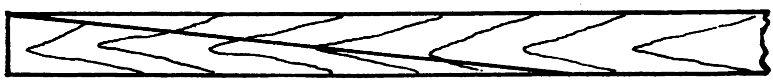
1. Flat steel washers.
2. Bevel steel washers.

Flat washers are used, under the heads of bolts, on all the wood parts that a bolt is used in the assembly. They distribute the tension of the bolt over a large surface, preventing the fibres of the wood from being broken. Bevel washers are used under the heads of bolts to shim the surface up, allowing the shoulders of the bolts to have a full bearing.

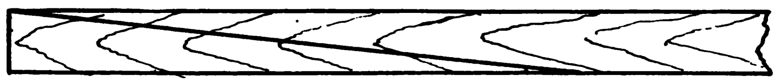
By this method a bolt will be assembled on the part at its maximum strength. The washers are case hardened and made proof against rust by copper plating and then nickle plating.

LONGERONS.

Longerons are made of high grade white ash. The advantages of using white ash for longerons are that it will hold its shape after being steamed. It is very strong under tensile, compression, and bending strains. The fuselage, being subject to severe strains when the aeroplane turns in the air, landing and



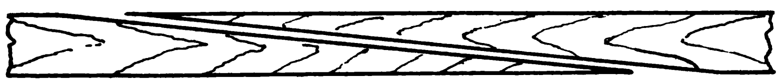
taxi-ing up the field, the need of great strength in these important members is obtained by using the very best of selected white ash. As white ash cannot be obtained in the lengths necessary for complete longerons, they are spliced in the center.



LAYING OUT THE SPLICE

The diagonal joint of the splice should be not less than ten times the diameter of the longerons. For greater strength, the splices should be perpendicular on each longeron of the fuselage.

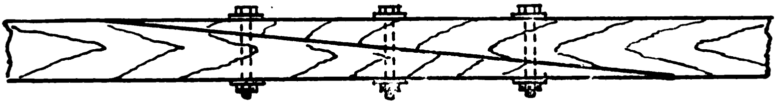
To make a longeron splice, lay the two halves of the longeron on a work bench; mark off the diagonal cuts and saw to shape. Plane the joints smooth, also checking for squarings. The splice



FITTING THE SPLICE

must make a perfect fit. Glue the splice and allow the glue to set, the splice being held rigidly in place by clamps.

After the glued joint is dry, drill the longeron to take three bolts with a diameter of one-quarter of an inch, the bolts being equally spaced along the splice, as shown in the illustration.



SECURING WITH BOLTS

Insert the bolts; first placing flat steel washers under heads; put steel washers on the other side of the splice before tightening the castellated nuts. The entire splice is now served with strong linen twine with a half hitch, securing each turn of the twine on one corner of the longeron.

WRAPPING THE SPLICE

To waterproof the wrapping, give the linen twine three coats of good shellac.

The following cautions should be taken into consideration when doing any work pertaining to the longerons:

Never drill a hole in a longeron unless necessary.

Never attempt to hide any bad workmanship by replacing the aluminum side cowls or the linen fabric.

Before replacing a fuselage cover, slightly round the corners of the longerons that the fabric will touch. If the linen fuselage cover is seen to be too slack and wrinkled after the aeroplane has made a bad landing, examine the fuselage closely for broken longerons or broken bracing wires. Be sure that the longerons are protected from the hot burnt gases coming from the exhaust ports.

PROPELLERS.

The propeller, sometimes called the airscrew, converts the rotational energy of the engine into the "thrust." This energy in a tractor machine is the means of driving the aeroplane.

The "thrust" is taken on the blades of the propeller and transmitted to the engine and crankshaft and thus through the engine to the aeroplane. The tendency of the propeller to draw the crankshaft forward when the engine is at full speed is taken care of by a thrust bearing. The relation of the thrust bearing in a tractor must differ with the pusher type. This is obtained

by changing the thrust bearing around for the kind of machine that the engine is to be used in. Some engines will have a thrust bearing that can be used on either tractor or the pusher type.

The thrust bearing will sometimes develop up and down "play" by the friction caused by lack of lubrication. When making an inspection of the machine, try the propeller for any excessive play. To do this, bring the propeller to the vertical position; then by holding the lower blade, try to move it up and down. Report immediately if any play is found. Excessive vibration in the engine would be the result and also consequent defective main bearings.

Various kinds of woods are used in propeller construction and it is always laminated. The woods used and their advantages are as follows:

BLACK OR AMERICAN WALNUT:

Light in weight. Easy to shape. Will take a very fine finish and does not warp if taken care of. The only disadvantage is that it cannot be obtained in the large quantities now required.

MAHOGANY:

Advantages are the same as Black Walnut.

OAK:

Very strong under the stresses that are set up in a propeller during flights and will be found to be the material used in the propellers on the average training machine.

This wood does not take as good a finish as Black Walnut or Mahogany, it also gives greater skin friction, but is counteracted by the efficiency in continued service. The three woods mentioned are the principal woods used in propeller construction. Propellers have been made out of "Papier Mache," "Bakerlite," Rosewood, Cherry and laminating Gumwood and Spruce. The last named is still often used in the construction of propellers of the pusher type.

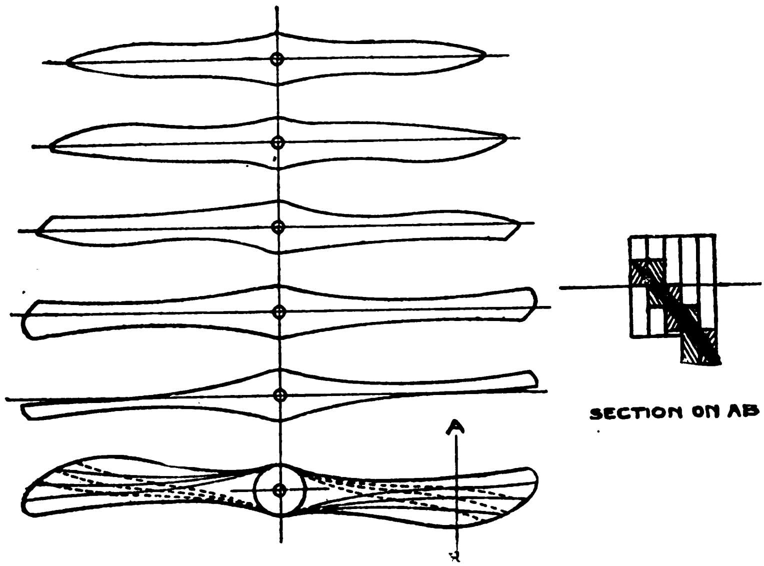
In the early days aeroplane propellers were made by hand by expert woodworkers. They are now shaped by means of propeller copying machines. The practice then was to laminate boards of equal length and width forming a solid block. The propeller was then shaped by hand. At least 40 per cent of the wood was wasted in shavings.

The practice today is to glue the laminations up in a fan shape and each lamination of a different shape as shown in the illustration. By this method boards may be used that by selecting the correct pattern, small defects can be cut out and thus give a saving of valuable material.

The finished propeller must be perfectly balanced and this is obtained by, in the first instance, putting the heavy end of one

lamination opposite the light end of the succeeding lamination. After the gluing is done, the fan shape block stands for some days and is then rough shaped. It then stands a few more days to recover from strains and is finally shaped to the required size.

The smooth finish to the propeller is given by hand, before varnishing. The propeller is carefully balanced after each opera-



The Five Laminations Composing the Propellor.

tion. The finished propeller is given several coats of varnish to cut down skin friction and to waterproof it. The final balancing is obtained by varnishing the lighter blade.

The rotation of a propeller is always taken as viewed from the pilot's seat, viz., clockwise or anti-clockwise.

The terms given to a wing apply in exactly the same manner to the propeller as: Leading and trailing edge, aspect ratio, chord, and the only difference is that the incidence angle is called the pitch angle and instead of calling the distance from propeller tip to tip the span, it is designated as the diameter.

The pitch of the propeller is the distance the propeller screws forward if it were rotated one complete revolution in a solid medium. Unfortunately it is impossible to have a 100 per cent propeller efficiency, owing to the difficulties in the construction for the great strength required for the attaching of the propeller to the crankshaft. Also the flexible quality of the air and the fuselage being directly behind the propeller, all help to decrease the efficiency. In favorable conditions with the engine at top

speed 75 per cent of the power of the crankshaft is taken up, the other 25 per cent being wasted and is known as the *slip*.

The lost energy of motion of the slip stream consists of the air driven back in the form of a spiral back draft.

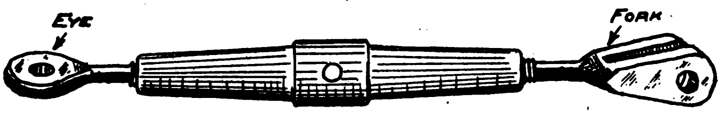
SHACKLES.

Used to connect loops of cables to anchors and the control posts, made of drop forged steel, copper and nickel plated.

Shackles should never be painted as the paint is liable to hide any cracks or flaws that may be in the steel. If left bright, flaws developing can be detected more easily.

TURNBUCKLES.

Turnbuckles are used on aeroplanes to apply tension on the bracing cables. All the adjustments on the cables for the alignment of the wings and controlling surfaces are made by tightening or slackening the turnbuckles.



Fork Turnbuckle.

Turnbuckles are composed of three parts, the center portion, known as the barrel, and the other two parts as shanks.

1. Barrel—Made of brass with an alloy of manganese.
2. Shanks—Dropped forged steel machined very accurately to shape.

Two types of turnbuckles are used, the fork and eye turnbuckle and the eye turnbuckle. The eye turnbuckle connects the loops of two cables together and the fork is used to connect a cable to an anchor. The barrel is of hollow construction tapped at one end for right hand threads and the other end for left hand threads. The shanks are screwed into the barrel, the forked shank always having a right hand thread and the eye shank a left hand thread.

Having the fork shank a right hand thread, the barrel is rotated to the right and this tightens the cable. The opposite effect is obtained by turning the barrel to the left. The strands of the cable are twisted to the right. By turning the barrel to the right an unwinding effect is eliminated from the cable.

When connecting the forked end of a turnbuckle to an anchor, be sure that the fork fits without any play. A diagonal bracing cable should be connected to the anchor at an angle of 45 degrees. The anchor is bent to this angle to give the correct

alignment to the cable and to prevent the turnbuckle from taking strains it was never designed to take.

After the necessary adjustments and correct tension have been placed on the cables by the turnbuckles, they are securely locked by 18-gauge soft annealed copper or galvanized steel wire. To lock a turnbuckle with an overall length of 8 inches, cut off a piece of locking wire 14 inches long. Insert one end of the locking wire where the forked end is connected to the anchor, allowing three inches to come through. Bend the longest portion of the wire straight up the turnbuckle. The short end of the wire is now bent up and wrapped about four turns around the shank. Insert the remaining free end of the wire through the hole in the center of the barrel and then through the loop of the cable. Pull the wire up tight at the same time and smooth out any kinks in the locking wire. Bend the wire over and wrap it tightly around the eye shank in the same method as used in wrapping it around the forked end of the turnbuckle.

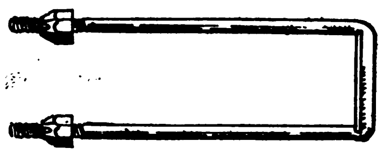
When disconnecting cables by the turnbuckles, screw the barrel well on the thread of the shank attached to the fixed part of the machine. The loose cables will often fall to the ground, but the threaded part of the shank can be more readily cleaned than the inside of the barrel. A mixture of engine oil and flake graphite mixed in the form of a paste makes a good lubricant for the threads. This will prevent rust and allow the barrel to turn easily.

Never use pliers to tighten or slacken a turnbuckle since this constitutes a criminal offense in the mind of an efficient aviation mechanic.

FITTINGS.

ANCHORS:

An anchor is the name given to a fitting that is fixed by means of brazing or welding or is held securely in place by a bolt. It is used in conjunction with either a forked turnbuckle or a

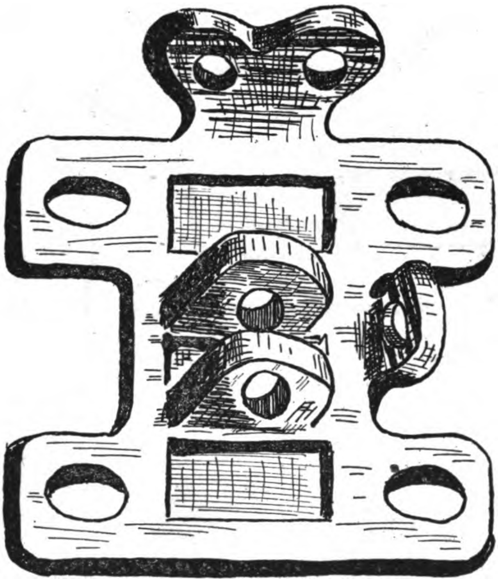


U-Bolt.

shackle. In the wing plate fittings, four anchors bent to the correct angles, take care of the landing, flying and stagger cables. These anchor plates are made of drop forged steel. The anchors, before being bent up to shape, are annealed at the bending points

to prevent the fracture of the steel. Anchors of lighter weight are used on the aeroplane and these are made from special sheet steel of very high tensile strength.

The excessive strains caused by faulty landings will often require the mechanic to replace, by making up these fittings himself. To do this, take the twisted or broken fitting off the ma-

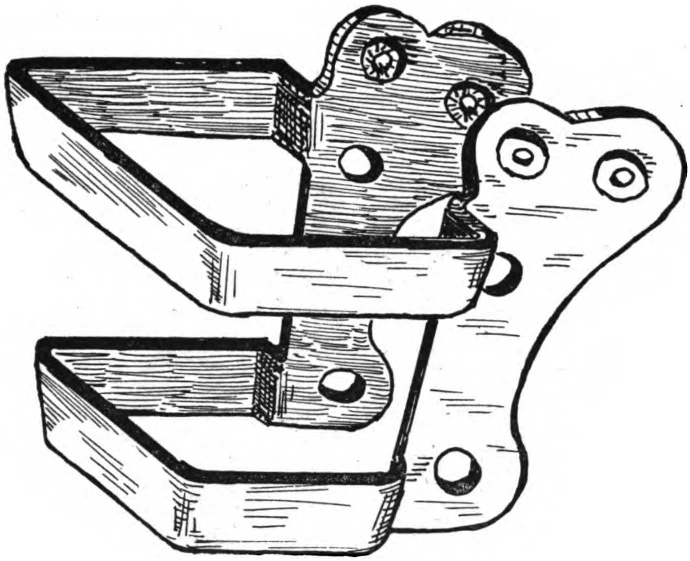


WING PLATE.

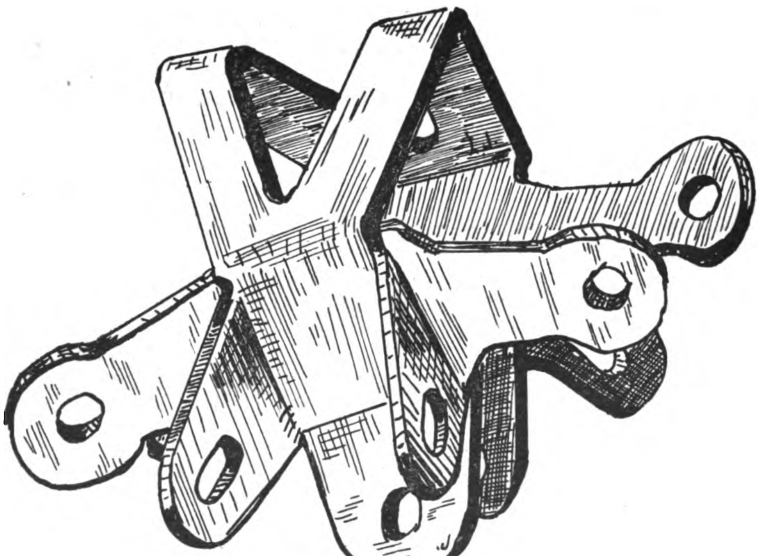
chine. Straighten out and flatten all the bends. Select a piece of the sheet steel of the correct gauge. Lay the flattened out fitting on the sheet steel and use it as a pattern. Mark the location of holes and the shape of fittings with a scratch awl and when the sheet steel has been filed to shape, center punch and drill the holes.

A precaution to take when drilling holes in sheet steel is to drill through the steel until the point of the drill just shows on the bottom side, then turn the steel over and finish drilling from the opposite side. This will prevent a ragged hole, also bruised or cut fingers in the operation of the drill press. A radius of not less than $\frac{3}{16}$ of an inch at the bend points is only considered a safe bend. Before bending, be sure to protect the sharp jaws of the vise with sheet aluminum. Paint the fitting after assembling to prevent rust.

CLIPS. (See next page.)



Tail Post and Longeron Clip.

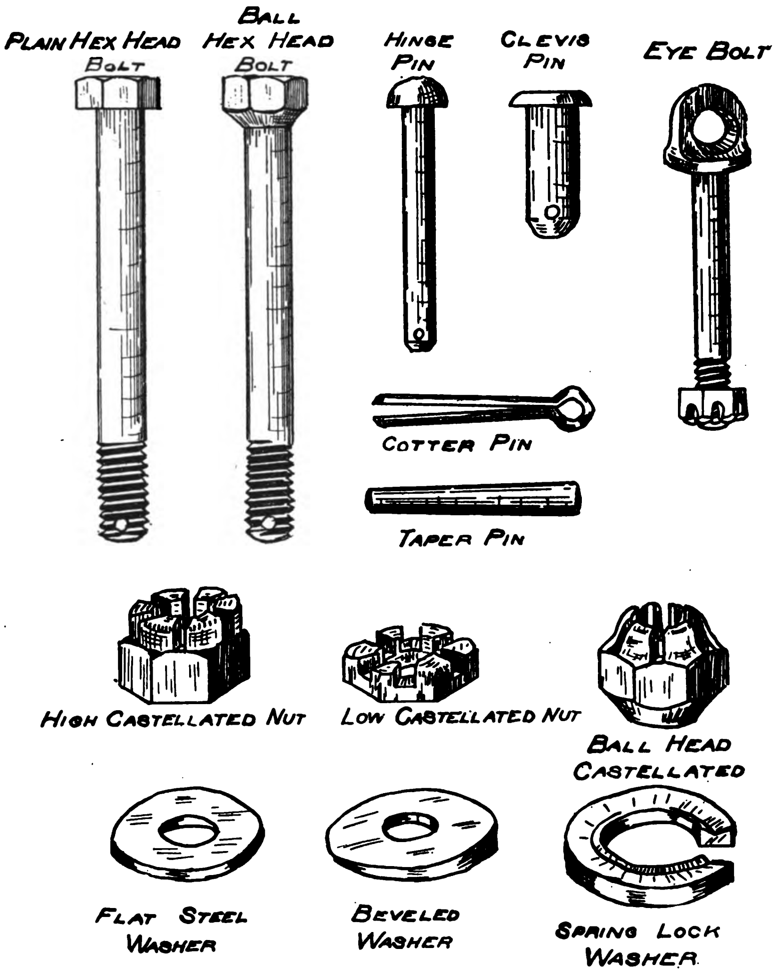


Fuselage Clip.

CLIPS.

Used on the longerons to take the diagonal bracing wires and spruce compression struts, made of sheet steel. They are copper plated and finally given several coats of black enamel, the black enamel being baked on the fitting in a gas oven.

BOLTS.



Two kinds of bolts are used in aeroplane work, plain hexagon head bolts and hexagon ball-head bolts, the only difference being that the ball-head bolts have chamvered shoulders instead of square shoulders as in ordinary bolts. The ball-head bolts are

found on the wings connecting the wing plates together.

The shoulders of these bolts are chamvered and only used on a fitting sufficiently thick to allow the holes to be countersunk. It will be noted that the top and bottom of a wing beam are set at different angles and the wing plates fit close to the surfaces. The wing plates will not be parallel to each other. This is taken care of by countersunk oval holes. The oval holes allow the correct alignment and still present a full bearing surface for the chamvered shoulders of the bolts. The ball-head castellated nuts are used with the bolts.

The lengths of the bolts are taken from under the head to the end of the bolt. When replacing a bolt, determine the correct size allowing just sufficient threads for the tightening of the nut. The bolts will then have their maximum strength. The bolts are made of 3 per cent nickel steel and have a very high tensile and shearing strength.

For the prevention of rust they are first copper plated and then nickel plated, but as an added precaution, always grease the bolts with vaseline before inserting in the woodwork.

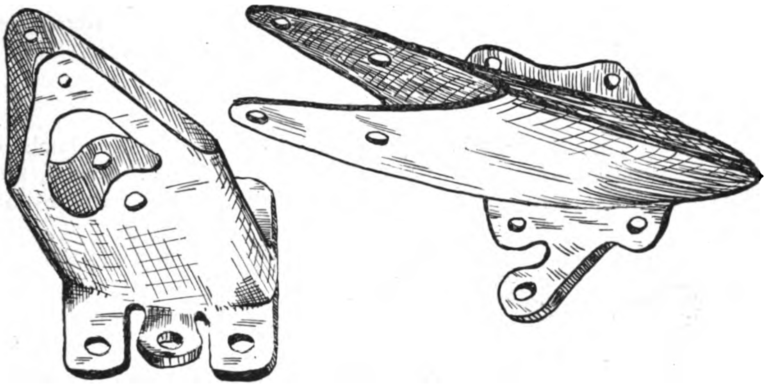
The following are the sizes mostly used in the assembly of the aeroplane:

Diameter of bolt $\frac{3}{16}$—number of threads per inch—32
Diameter of bolt $\frac{1}{4}$ —number of threads per inch—28
Diameter of bolt $\frac{5}{16}$—number of threads per inch—24
Diameter of bolt $\frac{3}{8}$ —number of threads per inch—24

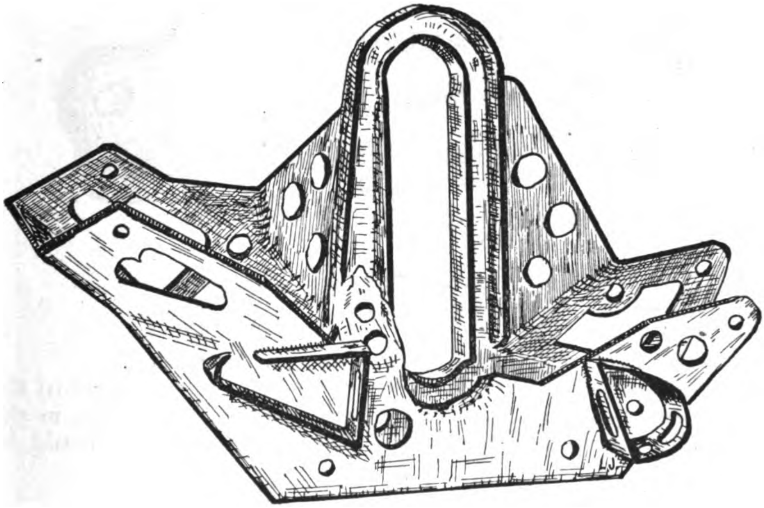
CASTELLATED NUTS.

These nuts are locked on the bolt with a cotter pin. This forms a safe and positive locking device, and it adds somewhat to the aviator's feeling of security when he knows that all the nuts are locked in this manner. The cotter pin holes in the bolts are usually drilled after assembly of the parts. Before drilling the cotter pin hole the nut must be pulled up tight. On the field, the bolts can be drilled by means of a small hand drill, but considerable care must be taken in drilling. The amateur at this work will often break several drills in the drilling of one hole, but he will become proficient with practice. Try to hold the hand drill rigid, and never force the drill. The drill should cut free and easy; if not, sharpen the drill with as small a bevel as possible.

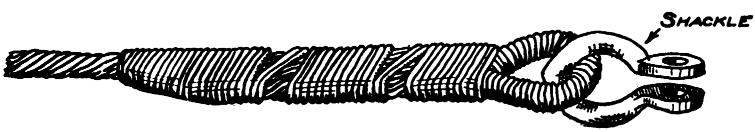
Plain hexagon nuts are sometimes used on aeroplanes. These nuts are locked by means of lock washers, or burring the threads on the end of bolts. The latter method should be only used in an emergency or when pressed for time. Lock washers should be only used in locking metal to metal and not when wood forms the center part of assembly. It can be readily seen that in order to squeeze the lock washer flat, the nuts will have to be pulled up



Landing Gear Strut Sockets, Front and Rear.



Left Axle Guide and Strut Sockets.

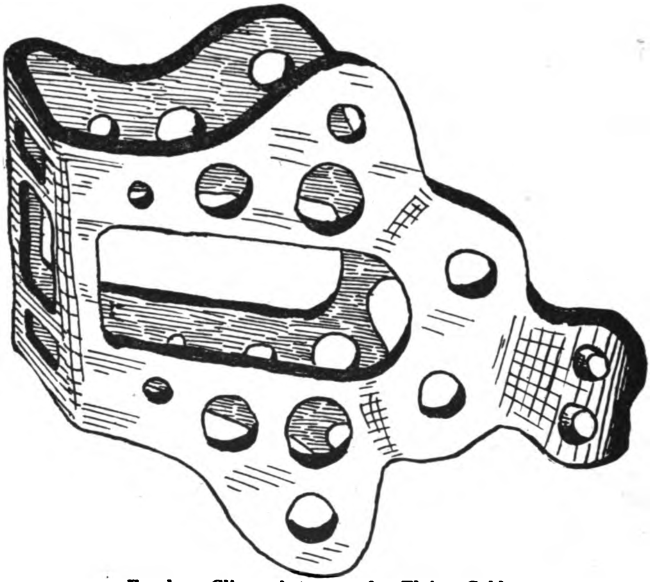


Curtiss Wire-Wrapped Joint.

very tightly. If this were done on a wooden member, the fibres would be broken and the strength of the wood decreased.

CLEVIS PINS.

Clevis pins are used to secure the forked end of turnbuckles and shackles to anchors. They are made of 3 per cent nickle steel and are afterwards copper and nickle plated. Lengths of



Fuselage Clip and Anchor for Flying Cables.

the clevis pins are taken from under the head to the center of the cotter pin hole. Locked with a cotter pin. When used in the assembly of the aeroplane, *heads* of the clevis pins should be *on top*.

STRUTS.

Made of spruce, as the requirements for struts are lightness and maximum strength under compression. Wing struts are stream-lined in form to cut down head resistance. All struts must be free from defects in any form as they are under a great compression strain by the tension placed on the cables.

Since it is not necessary to stream-line the fuselage struts, they are square in cross section. Struts, being under a strain of direct compression from both ends, the resultant of the strain would be the bending of the strut in the center. This is taken

care of by increasing in thickness the center of the strut and gradually tapering toward the ends.

Ends of struts that are fitted into metal sockets are protected

Wing Strut Socket.

Engine Section Panel Strut Socket.

by sheet copper, and the fit should be so perfect that they can be tapped gently into place, without the use of a sledge hammer. All struts must be protected from dents, abrasions or scrubbing of the surfaces when assembling.

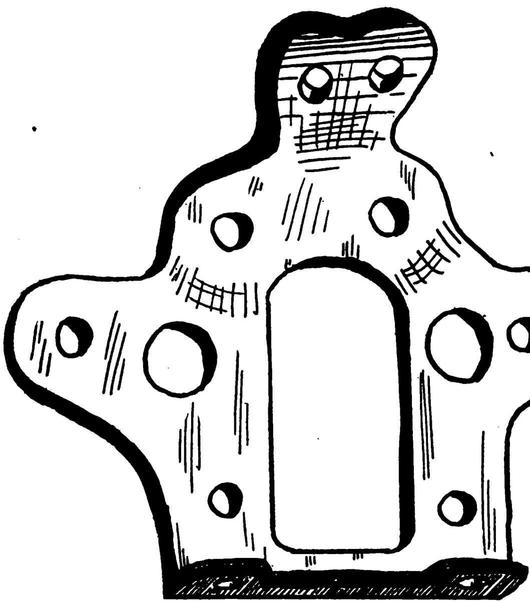
CABLES.

Three distinct types of cables are used in the construction of aeroplanes.

1. Hard cable or non-flexible cable
2. Flexible cable
3. Extra flexible

HARD CABLE:

Made up of 19 single strands of steel wire twisted up very tight. To facilitate the soldering of the cables they are coated



Fuselage Fitting.

with pure tin or galvanized. This type of cable being stiff and very strong, it is used extensively for the landing, flying and stagger cables. Even after the severe shocks caused by bad landings, the wings are held in alignment, owing to the non-stretching quality of this type of cable. The greatest proportion of weight is carried in the forward portion of the fuselage and consists of the engine, fuel and passengers. The use of hard cable for the diagonal bracing cable gives this additional strength. The safety factor of the fuselage is greatly increased by duplicating the cables in these sections.

FLEXIBLE CABLE:

A seven stranded steel cable, six of the strands twisted around a seventh strand, the centre strand usually called the (heart wire). Often used for the diagonal bracing cable on the parts of the machine which are subject to excessive vibration. This type of cable is best suited for the control cables. It will bend and run freely when led through fair leads or around pulleys.

EXTRA FLEXIBLE CABLE:

A stranded steel cable and very flexible. Used in connecting together the dual control wheels which operate the ailerons. A flexible cable is necessary, owing to the sharp turns that the cable will have to make. The friction, that would result in these severe turns, is taken care of by ball bearing pulleys attached at the angles of the cables. The diameter of all cables are given in thirty seconds of an inch, starting at 1/16, 3/32, 1/8, 5/32, 1/4 and upwards.

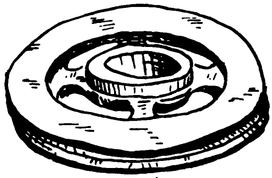
The following faults being found on a cable, it should be condemned and immediately replaced with a new cable:

Strands untwisted and daylight being noticed through the strands of the cable.

Kinks in the cable.

Strands broken. These will be usually found where the control cable runs around pulleys.

Bad workmanship on the soldering and wrapping of a wire wrapped joint.



Pulley Wheel.

The extra tension placed on the flying cables when the aeroplane is in continuous service will cause these cables to stretch. The amount of stretching will be noted by the mechanic by the adjustments he will have to make at frequent periods. This constant tension will through time shrink these cables to about two-thirds their original diameter. When the opportunity offers, replace the cables showing any shrinkage in diameter. An

excellent preservative for cables can be made from the following materials:

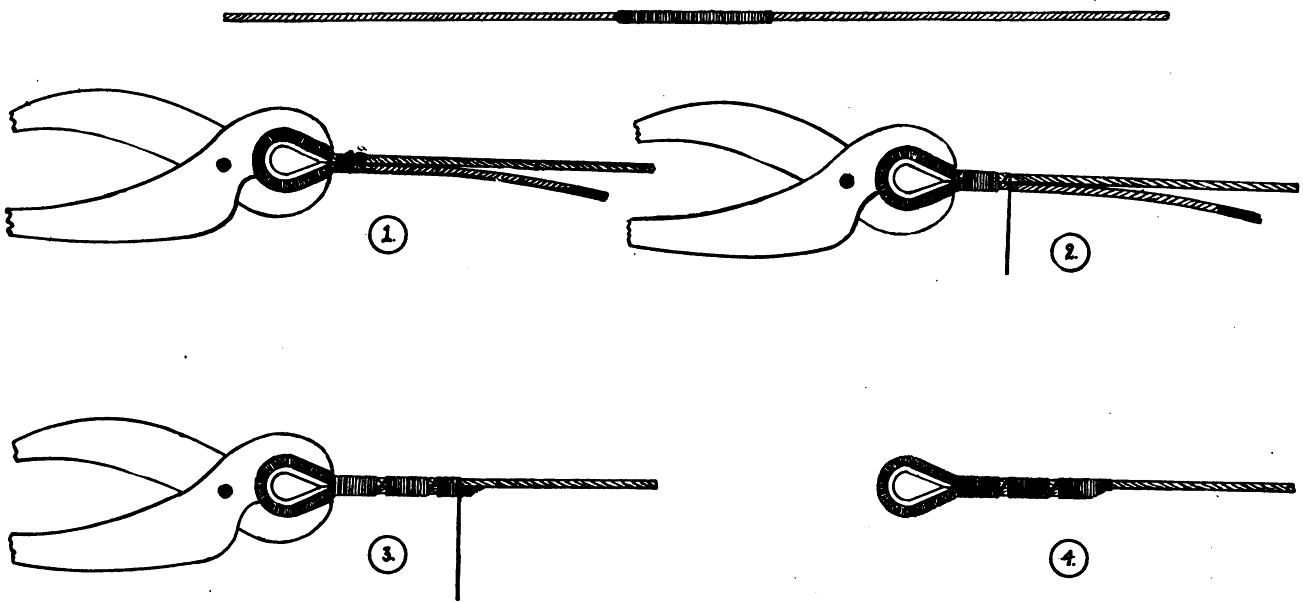
1 part engine oil
1 part acetone
1 part Parafine wax

Cables should be coated with this water-proofing mixture every day.

MAKING A WIRE WRAPPED JOINT.

Taking for an example a cable required with a diameter of 5/32 of an inch. Determine the location of the loop. Wrap tightly for a distance of two inches with 22 gauge soft tinned annealed wire or annealed copper wire. Bend the served portion of cable around the thimble, making sure that the cable fits snugly. Some difficulty will be experienced in holding the cable to the thimble. This difficulty can be overcome by the mechanic, making up a special tool for this purpose, in his spare time.

To make this tool take an ordinary pair of combination pliers, mark on the side of the closed pliers the shape of an average sized loop. Disconnect the two halves of the pliers and grind the jaws to the required shape on an emery wheel. In the operation of grinding the jaws of the pliers, the case-hardened surface will have been removed; and the jaws can be rounded out by means of a rat-tail-file. Assemble the two halves of the pliers. The jaws will now be seen to form the shape of a loop. Grip the loop with the special pliers until the short end of the cable fits tightly to the side of the cable proper. Secure the handles of the pliers in a wise. This will allow the use of the two hands in wrapping the cable. It will materially help if the right side of the vise is used. Cut off a piece of 18 gauge wire three feet in length and start wrapping the cables, where the serving on the outside of the loop finishes. Wrap tightly for 3/4 of an inch, then carry the wire diagonally across making a space of one-quarter of an inch; begin wrapping the wire again at right angles to the cables until a length of three-quarters of an inch has been covered. Make another space of one-quarter of an inch by bringing the wire across diagonally; wrap again until 1/2 an inch has been covered. The free end of the cable now being held securely by the wrapping wire, it can be cut to the finished length of the splice. Cut off the cable giving it a taper finish by cutting out a number of the steel strands. Continue wrapping until the wrapping wire terminates at the end of the tapered cable. The last wrapping should cover a length of not less than one inch.



Operations in Making a Wire Wrapped Joint for Stranded Steel Cable.

SOLDERING A WIRE WRAPPED JOINT.

The entire splice including serving and thimble must now be soldered and the solder must be thoroughly sweated in. The heat necessary to melt the solder must be applied to the splice with no danger of drawing the temper of the steel wire. The cleaning compound or "flux" must be of a non-corrosive nature. Muriatic acid neutralized with zinc, being too strong in its action, should never be used. Special preparations in the form of a paste are manufactured. Paint the splice with the paste. Clean the soldering iron by rubbing the iron on rock sal ammoniac. Melt the solder with the soldering iron, allowing it to flow freely on one side of the splice. The soldering iron should now be held on the underside of splice, since the heat will melt the solder on the top-side of the splice and running through in its melted state will, when cooled off, fill the splice solid.

Solder the thimble to the serving on the loop. Clean the completed splice with a rag while it is still warm. This will remove the dirt and melted soldering paste.

PIANO WIRE OR SOLID WIRE.

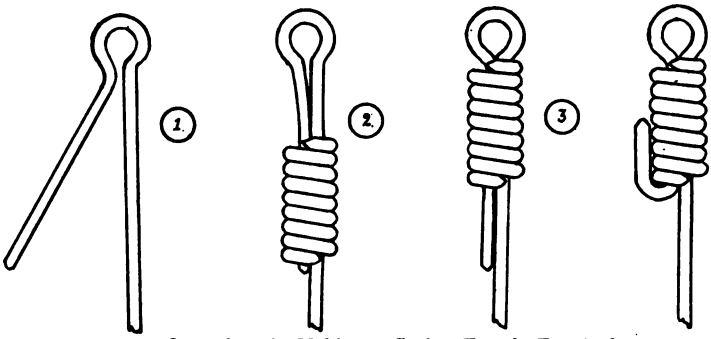
Made of highly tempered steel coated with pure tin to solder readily. It has a very high tensile strength. A danger of crystallizing of the steel in its composition may become, if used on sections of the aeroplane, subject to excessive vibration. The diagonal bracing wires of the fuselage from the pilot seat to the tail post are made of this solid wire. As this portion of the fuselage is situated at some distance from the engine, piano wire can be used safely for the diagonal bracing wires.

Intersecting points of the diagonal bracing wires should be fastened together with insulating tape to prevent any vibration. The bracing wires in the fuselage are given three coats of black enamel as an extra precaution against rust. The diameter of the piano wire corresponds to the Standard American Wire Gauge (Brown and Sharpe Gauge).

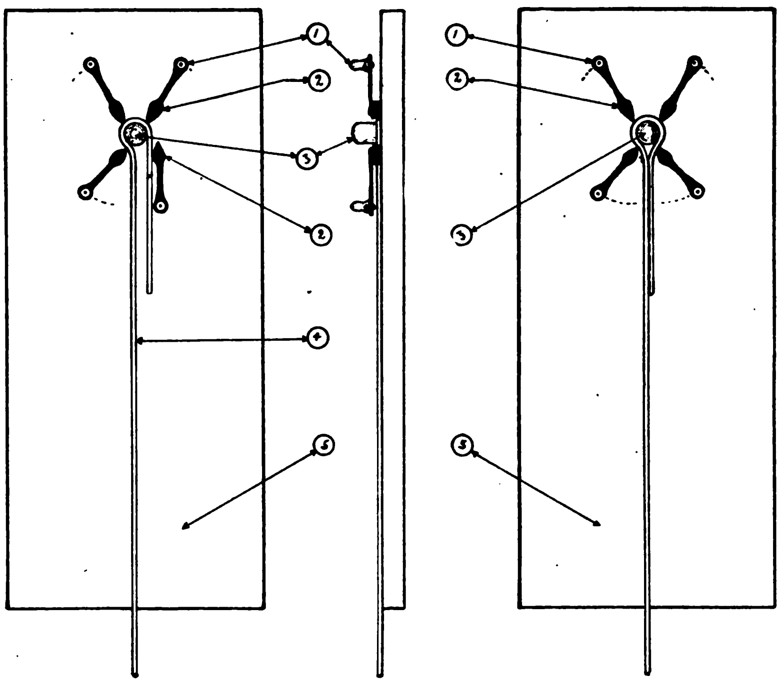
TO MAKE A PIANO WIRE TERMINAL.

The method used in the making of the terminals for a diagonal brace wire is much simpler to make than a wire wrapped joint. The piano wire is secured at the loop by means of a spring ferrule in place of the wrapping wire as used on the stranded cable.

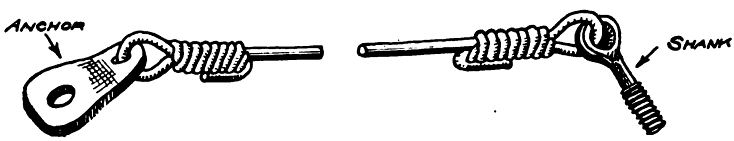
The following illustrations will show plainly the operations necessary to make the terminals. It will be seen in the completed terminal that the loop forms a perfect circle. This is the only loop considered safe. The loops can be made by a special tool now used in most flying schools. If the special tool is not avail-



Operations in Making a Spring Ferrule Terminal.



JIG FOR MAKING PIANO WIRE TERMINAL.
1. Handles. 2. Cams. 3. 5-16 Steel Pin. 4. Piano Wire. 5. Steel Plates.



Piano Wire Terminals.

able the loop can be bent to shape by securing the piano wire in a vise and bending the wire around a piece of 5/16" drill rod. This primitive method of making the loops can be eliminated by making up a jig operated in the same manner as used in a cam action. After the spring ferrule has been slid up and fits tight up against the shoulders of the loop, bend the short end of the wire until it fits as close as possible to the side of the ferrule. Extra leverage can be exerted in the bending up of the short wire by sliding over the end of the wire a piece of steel tubing with an inside diameter a little larger than the outside diameter of the piano wire. In an emergency it is not absolutely necessary to solder this type of terminal, but if possible solder.

PAINTING AND GREASING OF WIRES:

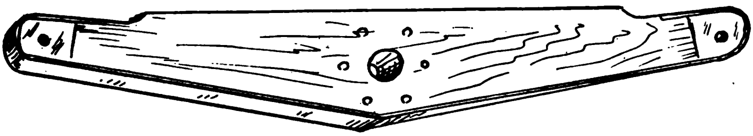
The wire and cable used in an aeroplane are protected against rust by painting, greasing or galvanizing them. All piano wires that are placed in the internal structure of the machine should be painted or black enamelled. Cable bracing wires that are used in the internal structure are frequently treated in a similar manner. The flying and landing cables are subjected to a constant vibration during flight and it is found best to wrap them at their intersecting points with insulating tape. Great care should be given to the control cables as they are subjected to rubbing as well as vibration. All fair-leads and pulleys should be kept well greased, and the cables inspected at these points before and after each flight for frayed strands.

FABRIC AND DOPING.

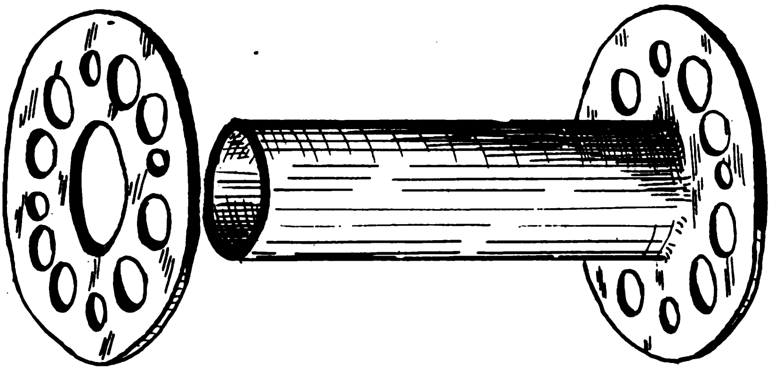
The fabric used on the modern aeroplane is made of high grade unbleached Irish linen. The yarns must be of uniform strength and regular in weave both for warp and woof. There must be no loose ends or knots. The number of strands should be from 92 to 96 per inch. The strength must be at least 91 lbs. per inch in the warp and 102 lbs. per inch in the woof.

The warp is the yarn running lengthwise. The woof or weft is the yarn running across the cloth and is woven into the warp.

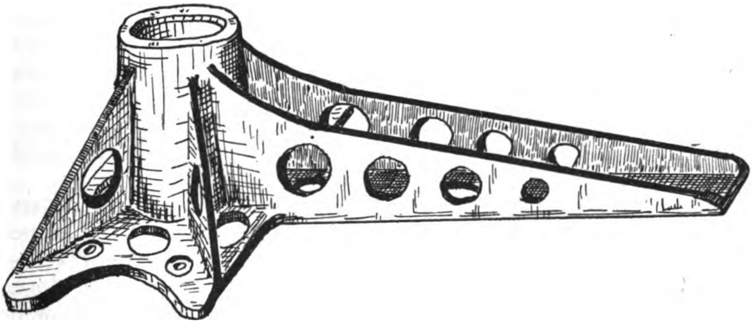
The fabric is sewn to the shape of the wing in the form of a bag, generally being double stitched by a sewing machine. The separate strips are sewn together so as to take a diagonal position in relation to the wing. This method of sewing the fabric is used by the majority of the present day manufacturers as it is supposed to give added strength to the bracing of the wings. The fabric cover is drawn over the wing frame from the outer end. It should make a snug fit all around. The fabric is tacked lightly to the rib caps of the wing with small copper tacks. These tacks should be placed about three to the foot, having just enough to hold the fabric in place. If too many tacks are placed in these



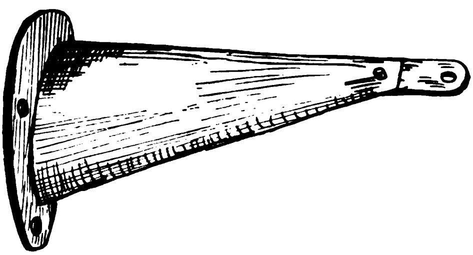
Rudder Bar.



Bushing and Plate for Rudder Bar.



Bráce and Swivel for Rudder Bar.



Control Post.

caps, there is a danger of splitting the thin spruce strips that the caps are made of.

Having the wings properly covered and the fabric loosely tacked, the next step is to secure the fabric firmly to the ribs of the wing. This is accomplished by stitching the fabric close to the ribs with a strong linen twine. A sail-maker's needle about 4½ inches in length is used, being long enough to carry the thread from the top rib cap through the plane to the lower rib cap. A knot is tied at the top of each stitch, then the twine is carried forward to the next stitch. The distance between the separate stitches varies from 3 to 4 inches. Each stitch should be drawn taut, as this sewing is the means that prevents the fabric from being drawn away from the rib caps when the contraction takes place as the dope dries upon it.

DOPING:

"Dope" is the term applied to the weatherproof and air tight coating of painting material applied to the fabric of aeroplane wings. The dope should be of light-weight, flexible, impervious to moisture, and flame-proof when dry. It should have a high coefficient of expansion and contraction, and be firm enough to withstand the general wear and tear.

Most paints used for this purpose are of a poisonous nature, especially where the paint contains tetra chlorethane. The gases from the paint are heavier than air so as a precaution against inhaling the poisonous gases a strong suction fan is placed near the floor to draw the fumes out of the fabric room. It can be seen from this that one should not sit on the floor or stand for any length of time between the work and the fan. The person applying the dope should work so that the fumes are being drawn away from the body by the suction fan.

The fabric is generally given six coats of dope, then two coats of Valspar or aeroplane varnish. The first two coats of dope should be rubbed well into the fabric filling the pores and preventing any air bubbles from forming in the paint. When the dope has dried, the resulting contraction of the fibres of the fabric will cause these air bubbles to break and in this way ruin the purpose of the doping.

Dope is applied with a stiff, flat bristle brush about 3½ inches wide. The bristles must be stiff enough to work the dope well into the fabric and long enough to make the brush pliable. The dope dries rapidly and the successive coatings may be applied without waiting long for the previous coating to dry.

The first two coatings should be of a heavier mixture than the following four. After applying the second coating attach strips of fabric over the rib cap sewing. These strips of fabric should be frayed or scalloped for at least a quarter of an inch on each side. The effect produced is to give the strip a great

number of tendrils, which are glued to the main fabric and prevent the strips from being torn off by the wind pressure. The object of these strips is to reduce the skin friction that is offered by the sewing.

To attach the frayed strips, attach one end under the trailing edge of the rib cap and stretch the strip over the sewing both on the upper and lower surfaces of the plane. Apply fresh dope to the wings where the strip is being placed as it is attached. There should be no time lost in applying the strips once the dope has been put on, as it dries so rapidly the adhesive properties are liable to be lost.

The remaining four coats of dope are then applied, after which the planes are given two coats of Valspar or aeroplane varnish, producing a smooth, glossy surface and giving extra waterproof qualities to the fabric. The planes should then be placed in a clean room and allowed to dry, where there is no danger of insects, dust or sand settling on them.

PATCHING OF FABRIC:

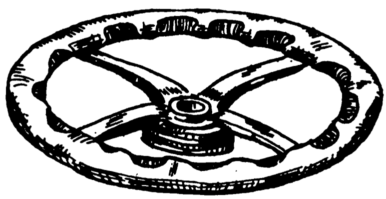
When the fabric on a plane is torn it should be immediately repaired as the air stream in flight is so strong that it will increase the size of the tear and is liable to strip the fabric off the plane. When the tear is small it may be covered with a small frayed patch of fabric, but where the tear is large or of right angle shape, it must first be stitched together with strong linen thread. The covering patch should be a good deal larger than the tear, and its edges should be frayed for at least one-quarter of an inch. It is given a coat of dope; then placed over the tear, taking the precaution to rub it flat and leaving no wrinkles. Several coats of dope are applied over the patch reducing the skin friction as much as possible.

CONTROLS.

There are two types of controls used on the modern aeroplane, but both types serve the same purpose and act in a similar manner. These types are:

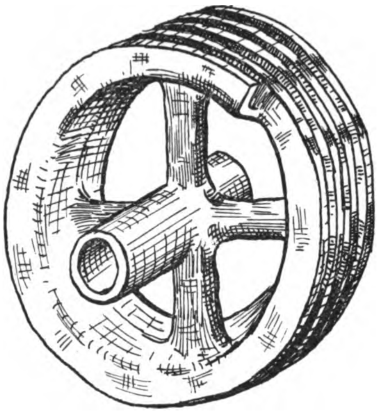
1. The "Stick" control
2. The "Dep" control

The functions of each type are the same. The lateral movements of the machine are controlled by warping the trailing edges



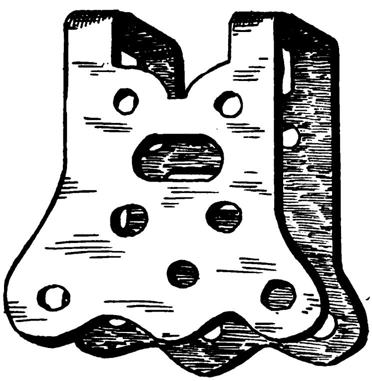
Control Wheel.

of the wings, or by warping the movable surfaces, known as the "ailerons." The longitudinal movements are controlled by warping the movable surfaces attached to the rear beam of the horizontal stabilizer; in other words, the elevators. The directional movements are controlled by the movable rudder attached to the tail post and the vertical stabilizer.



Aileron Control Drum.

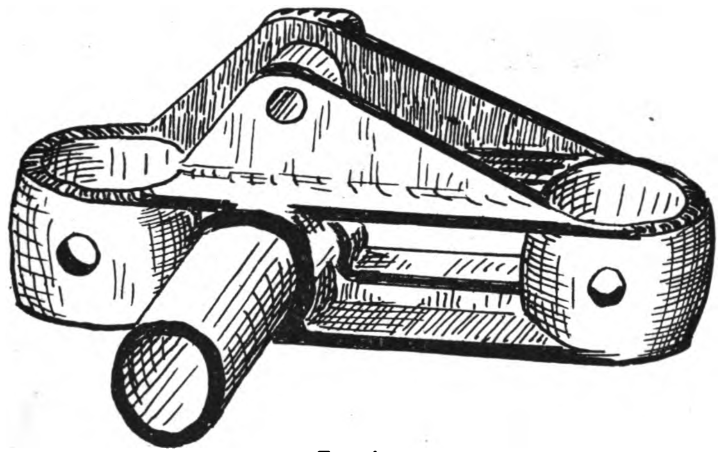
The stick control has, as the name implies, a stick, which is mounted on a ball and socket joint. The elevator control wires and the aileron control wires are attached to this stick in such a manner that the controlling surfaces are warped so that the machine follows the direction of the movement of the stick. For this reason, the stick control is the most natural control that could be adopted to the machine. It is the most popular type of control,



Fusealage Clip.

but unfortunately, can only be used on machines which are comparatively light on the controlling movements. Land machines, with a few exceptions, are equipped with this type of control, whereas seaplanes and the larger type of land machines are usually equipped with the "Dep" type of control.

The "Dep" control has a control yoke or column, to which are attached the elevator control cables. There is a control wheel and drum attached to the upper part of this control yoke. The aileron control cables are secured to the drum, and since the drum has from three to four windings, a much greater leverage is obtained for the lateral control of the machine than that of the stick control.



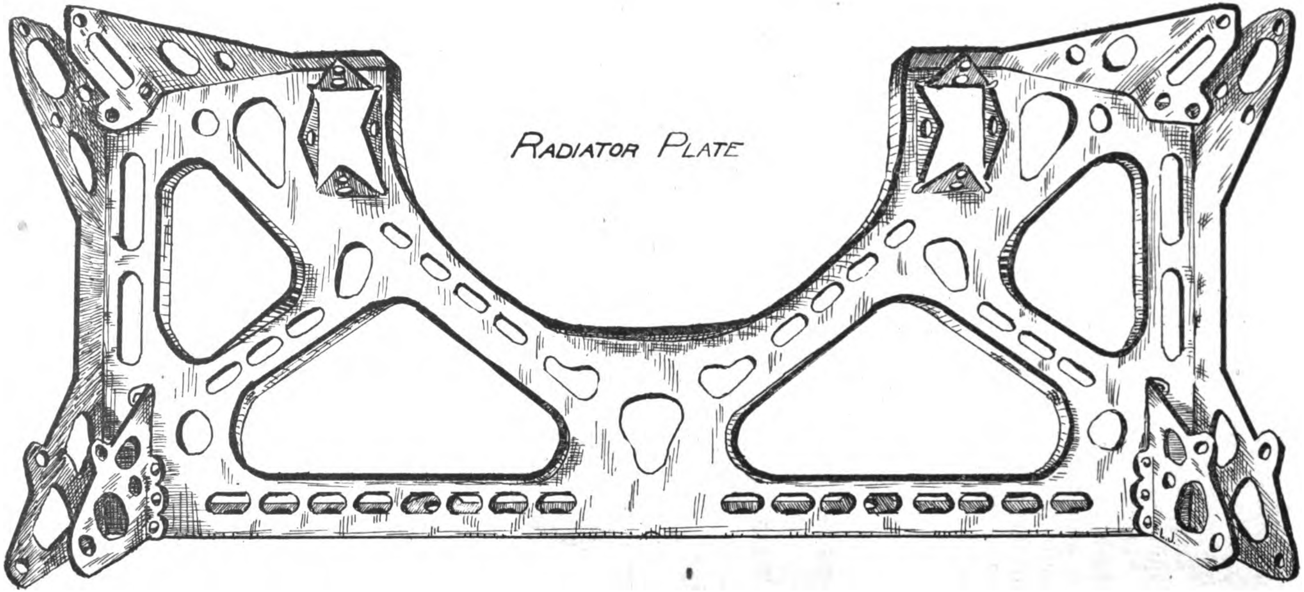
Trunnion.

The nose of the machine is raised or lowered by a fore and aft movement of the control yoke, while the banking movement is controlled by the lateral movement of the wheel.

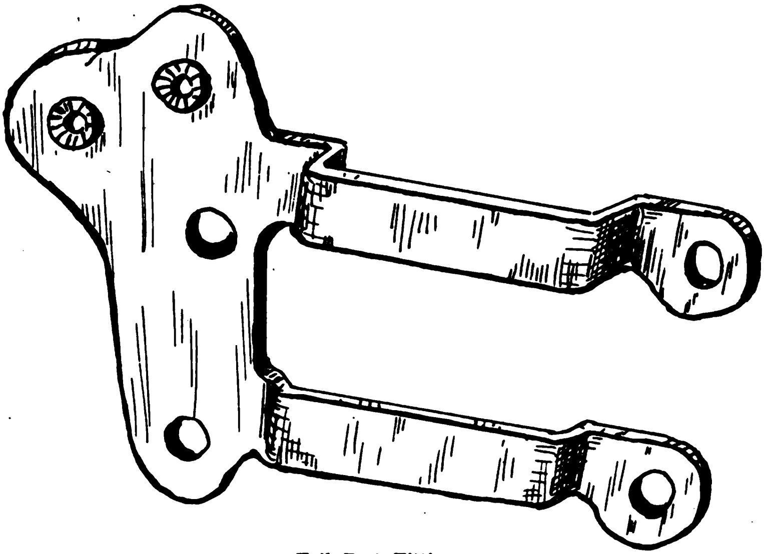
The directional movement is controlled in both cases by a movable rudder bar pivoted on the floor boards near the pilot's seat.

In order to equip a machine with "Dual control" a similar yoke or stick is placed in the passengers cockpit, and another rudder bar is pivoted to the floor boards in front of the passenger's seat. This rudder bar is connected in a parallel position to the pilot's rudder bar. The dual control for the fore and aft movement of the yoke or stick is generally obtained by connecting the two control columns with a steel rod or rods, which makes this movement positive in the passenger's controls.

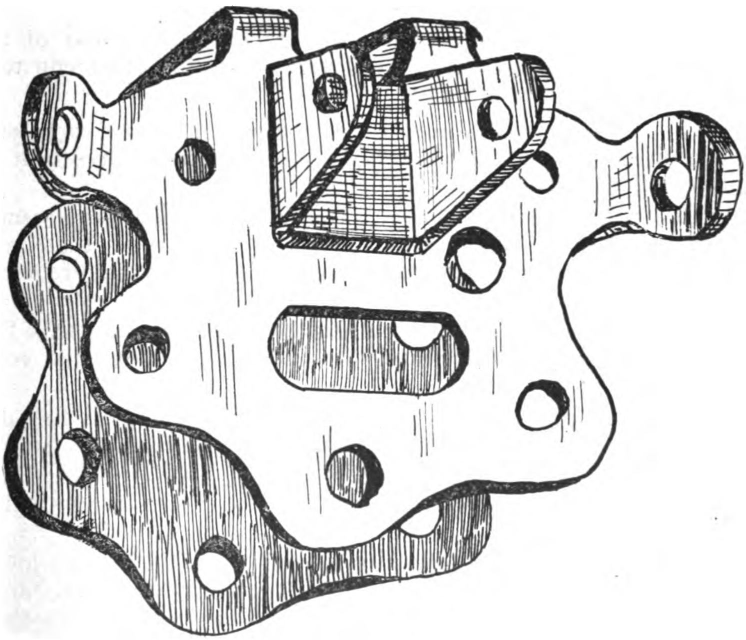
The aileron control wires are connected to the drum or to the lever arms of the stick in the passenger's control column so that they work in conjunction with the lateral movements of the controls in the pilot's seat.



RADIATOR PLATE



Tail Post Fitting.



Fuselage Clip.

ALIGNMENT OF THE FUSELAGE.

Various methods are used in the alignment of the fuselage. The fuselage must be stripped completely for the trueing up. It will be necessary to number the struts so that the methods explained below can be readily understood. Starting at the front of the fuselage is situated the radiator or nose plate. The radiator plate is made of sheet steel and is securely bolted to the ends of the four longerons. The compression struts, directly following, are numbered and designated as Station No. 1, 2, 3, 4 and upwards until the tail post is reached. The struts decrease in length beginning at Station No. 5, thus giving a tapering effect to the longerons and the stream line form to the fuselage. Always when trueing up the fuselage, give the diagonal bracing cables in the sections 1, 2, 3, 4 and 5 extra tension to take the extra weight, which will be placed there.

METHOD No. 1.

1. Place the fuselage on trestles situated under Stations 3 and 7, the *trestles* being *leveled* and securely nailed to the floor.

2. Remove the locking wires from all turnbuckles and loosen all diagonal bracing wires slightly.

3. Mark the exact center on the top side of all the compression struts on the top and bottom of the fuselage.

4. Attach one end of a chalk line from the center of the first horizontal compression strut, and secure the other end to a small nail in the center of the tail post.

5. The line should intersect with center marks on each compression strut. Find the strut with the center mark most out of place with the chalk line.

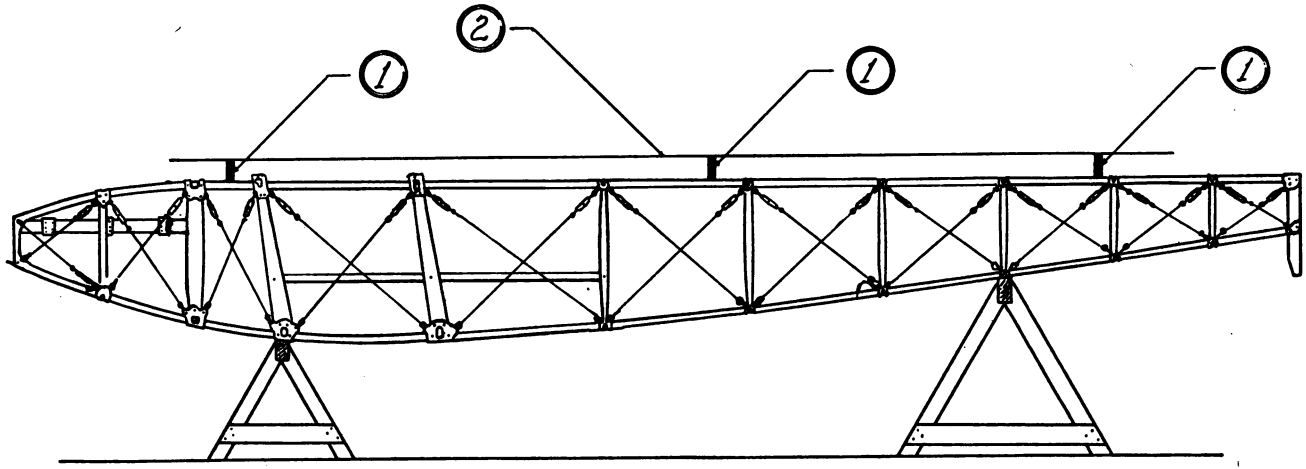
6. Select the two cables that by tensioning will bring center mark on the strut to correspond with the chalk line. (*Caution*—loosen the *opposing two cables* before applying this required tension.)

7. Follow this operation in each section until the chalk line intersects with the center marks on each of the horizontal compression struts.

8. Now take three straight edges of equal width. Lay one on the top of the longerons at Station No. 2, the next at Station No. 6 and the third straight edge at Station No. 9.

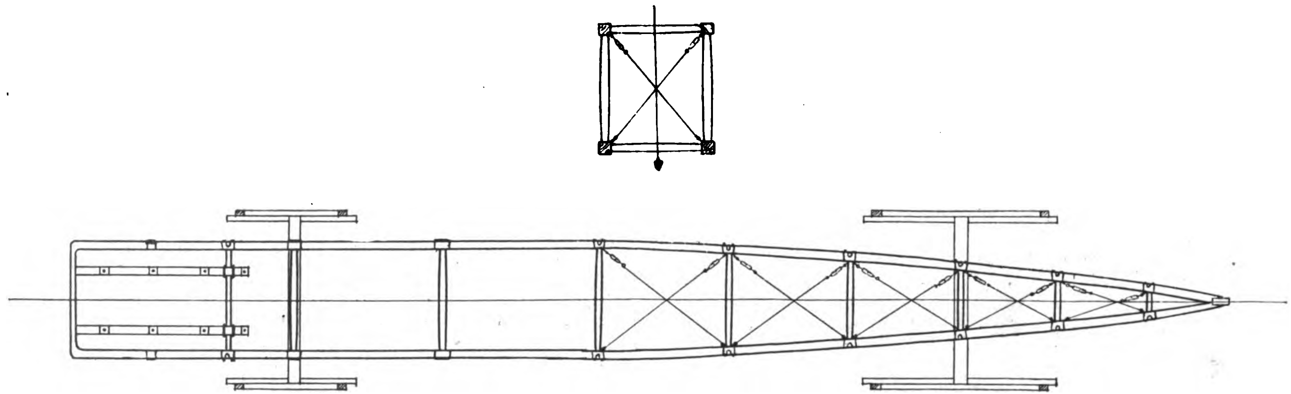
9. Adjust the internal diagonal bracing wires until the top of these three straight edges are *level.*

10. If the straight edge in the center is seen to be lower than the two straight edges situated at Stations No. 2 and No. 9, adjust the diagonal bracing wires on the sides of the fuselage until all three straight edges are level. A positive check can be



FUSELAGE ALIGNMENT
FIRST METHOD

(1) Steel Straight Edges
(2) Chalk Line



FUSELAGE ALIGNMENT
FIRST METHOD

made by attaching a cord to the ends of straight edges No. 1 and No. 3 and adjust the bracing wires on each side of the fuselage until the center straight edge just touches the underside of the parallel cords.

11. Having three determined and fixed points, the sections in between the straight edges can be trued up by means of a spirit level laid on top of the longeron and adjusting the wires in each section to the required alignment. (*Caution*—check the *fuselage* again for *level.*)

12. It is not practical to stretch a cord lengthwise for trueing up the bottom side of the fuselage owing to the shape of the fuselage. This is obtained by dropping a plump bob from the center mark on the top of the horizontal struts and adjusting the bottom diagonal bracing wires until the plumb line intersects the center marks of the bottom horizontal compression struts. Follow this operation right through the fuselage.

13. Check all the diagonal brace wires in the fuselage for tension, paying particular care to wires that are duplicated; these must be at equal tension. Lock the turnbuckles with *new safety wire.*

METHOD NO. 2.

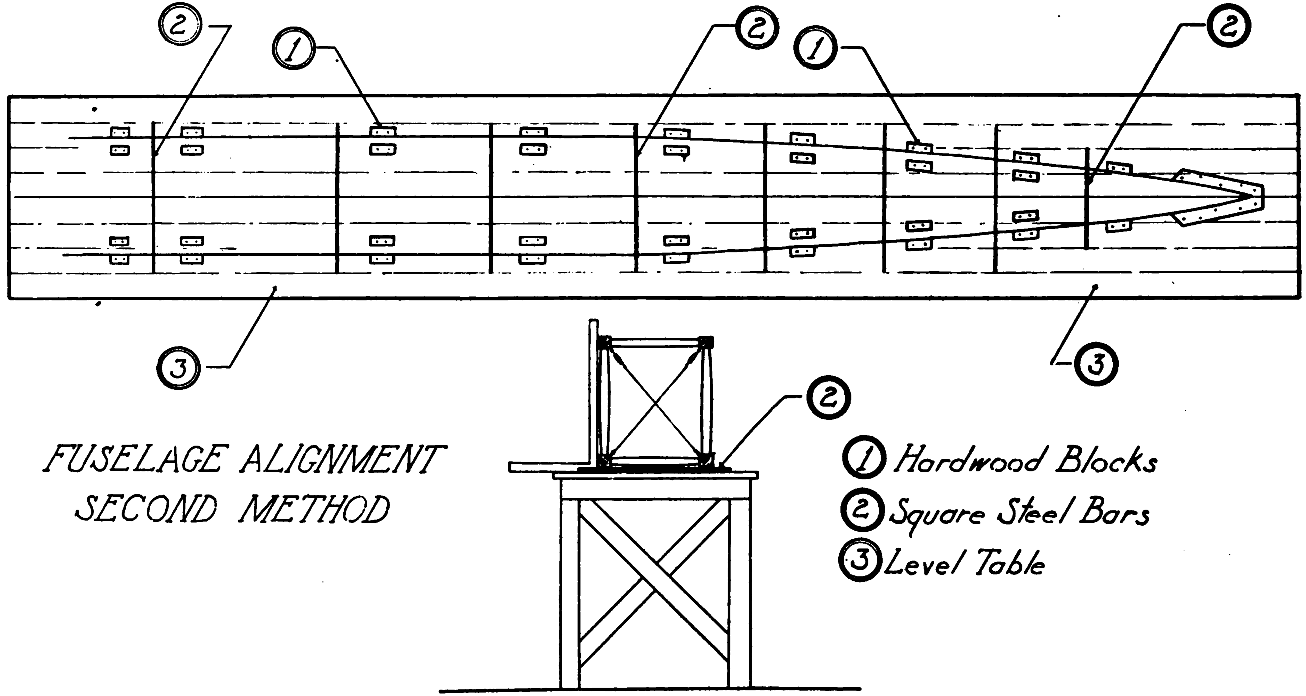
This method of alignment can be used to great advantage in flying schools that have a great number of aeroplanes of the same design and make.

1. Construct a table with a length of 25 feet and a width of 3 feet 6 inches. The table top is to be perfectly level and the supports well braced and secured to the floor.

2. Stretch a cord and secure the ends to nails placed in the center of both ends of the table top. This furnishes a center line for the measurements now taken. Transfer full size, and very accurately, the dimensions of the top side of the fuselage to the table top, the measurements to be taken from the blue prints that are provided with each machine.

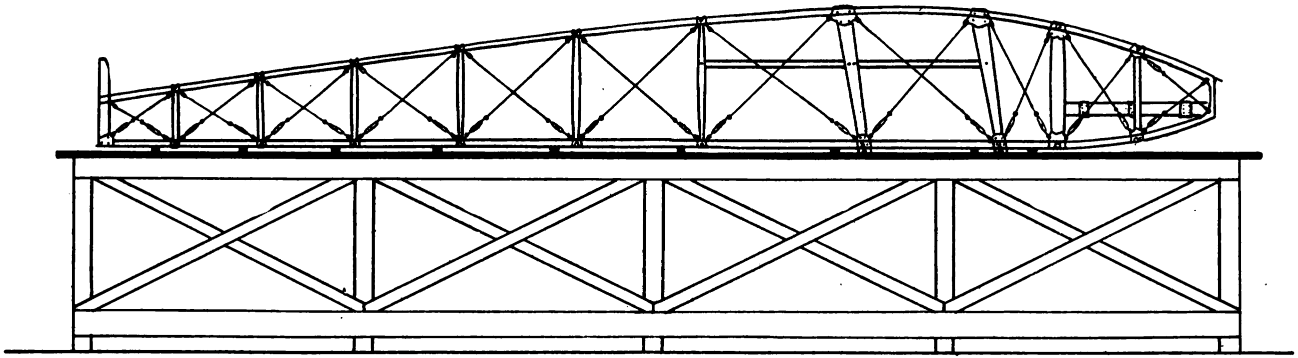
3. Hardwood blocks are now screwed to the table top, and 1-inch steel square blocks are placed in the center of each section, as shown in the illustration.

4. Slacken all diagonal bracing wires in the fuselage. Now place the fuselage upside down on the table. The longerons will fit in between the hardwood blocks and should touch the steel blocks. Two operations are combined in one by this method of alignment: the straightening of the top longerons, and all warps taken out of them. Bring the diagonal bracing wires on both sides of the fuselage and the side that is now held rigid on the table to equal and correct tension.



FUSELAGE ALIGNMENT
SECOND METHOD

FUSELAGE ALIGNMENT
SECOND METHOD



5. Now butt a steel square against the struts at each station and adjust the internal diagonal bracing wires until the top struts are perpendicular to the side struts. Particular attention should be given to the tail post. A final check for tension on all bracing wires should now be made and being proved satisfactory lock all turnbuckles.

COMMON FAULTS IN RIGGING.

The inefficiency of an aeroplane in flight can be usually traced to inaccuracy in design, measurements and the angles used in rigging, also defective or warped surfaces.

The following faults in rigging and their remedies should be noted:

1. Difficulty in landing smoothly. Elevator control cables with too much tension on them. Just as difficult to land with these control cables too slack.

To Remedy: Adjust cables to correct tension with the elevators held in stream-line position.

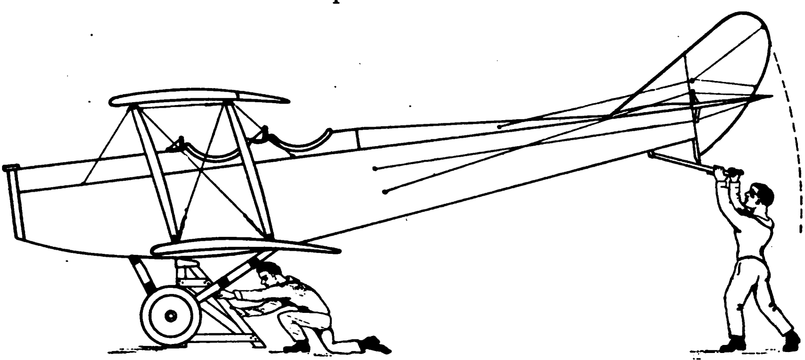
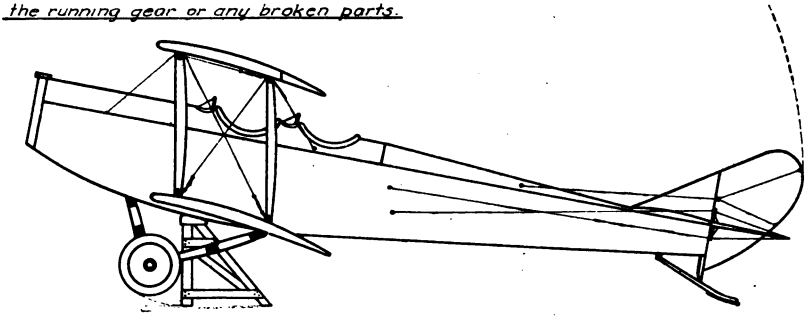


Fig. 1 & 2 show the method that two men can raise the machine to replace the running gear or any broken parts.



2. Landing gear too far back of the center of gravity or too far in front of the center of gravity. The former giving a clockwise movement to the machine and the latter an anti-clockwise movement to the machine, when the wheels touch the ground.

To Remedy: In both cases have new landing gear struts made and change the angles on top of the struts, thus changing the position of the wheels.

3. Landing gear not assembled squarely on the fuselage. This will cause one wheel to take the shock first, often breaking the diagonal bracing cables subject to this side thrust.

To Remedy: Check up lengths of struts and the true alignment of the landing gear.

4. Shock absorbers too slack.

To Remedy: Lift the machine so that the weight is taken by a trestle, placed under the load points. Tighten the rubber shock absorbers until both are at equal tension.

The machine can be lifted for any adjustment of the landing gear by the method shown in the illustration.

NOSE HEAVY.

1. Not enough stagger. Will bring the center of lift too far back.

To Remedy: Place machine in flying position and check the stagger.

2. The "U" bolts securing the leading edge of the horizontal stabilizer may be loose, allowing the stabilizer to move up, giving an incidence angle to the horizontal stabilizer, and so causing lift to this surface.

To Remedy: Tighten down the "U" bolts and give a thorough inspection.

3. If the machine has an adjustable incidence on the horizontal stabilizer, decrease the incidence angle.

4. Alignment of the fuselage may be wrong, giving incidence and lift to the horizontal stabilizer by being warped down towards the tail.

To Remedy: Strip and realign the fuselage.

5. The location of the holes for the securing of the engine to engine beds may have been drilled wrong.

To Remedy: Check the location of the holes by the blueprint; if found wrong, replace with new engine beds.

TAIL HEAVY.

1. Too much stagger.

To Remedy: Place fuselage in flying position and check the stagger.

2. If the horizontal stabilizer is adjustable, increase the incidence angle.

3. Holes drilled wrong for engine bolts.

To Remedy: Same as No. 5 in "Nose Heavy."

RIGHT OR LEFT WING FLYING HIGH.

1. Too much incidence in one wing.

To Remedy: Place the machine in flying position and check the dihedral angle and the incidence angle.

2. Distorted surfaces.

To Remedy: Straighten the flattened steel tubing forming the trailing edge, if bent out of shape.

3. Not enough tension on the flying cables on one wing. The alignment of the wings will change when the machine is in flight, owing to the wings taking up the slack of the flying cables.

To Remedy: Bring all flying cables to equal tension.

4. Too much wash in or droop may have been put in one wing.

THE AEROPLANE TENDS TO PULL TO RIGHT OR LEFT.

1. Holes drilled for the bolts to secure the engine being drilled not parallel to the center line of fuselage, causing the propeller to pull to either the left or right.

To Remedy: Repace with new engine beds, and drill holes correct.

2. Vertical stabilizer, not being stream-line with center line of the fuselage. Will act as a fixed rudder if not counteracted by the aviator.

3. May be caused by the holes in the horizontal stabilizer being drilled wrong or the forward connection of the vertical stabilizer not being in the exact center of the front beam of the horizontal stabilizer.

To Remedy: Replace with a new horizontal stabilizer.

4. Too much tension on the right or left drift cables will cause the wings on one side of the machine to be drawn forward.

To Remedy: Mark with a pencil the exact center of the leading edge of the horizontal stabilizer. From this determined

point, measure by means of a steel tape to definite points on the two outer wing plates on the rear of each wing. Adjust the drift cables until these measurements are of the same length.

5. Warped Fuselage. The fuselage twisted to either left or right. Tail post, not being at right angles to the horizontal stabilizer, and the rudder being attached by hinges to the tail post, it would not be in correct alignment.

To Remedy: Strip and realign the fuselage.

INEFFICIENCY IN CLIMB AND SPEED.

1. Loose Fabric. Caused by the dope cracking the effect of extremes in temperature and the suction effect of the reaction on the upper surfaces. Slackening of the fabric will spoil the curvature of the wing, and thus decrease its efficiency.

To Remedy: Choose a dry warm day and then dope all surfaces showing any slackness.

2. Too Much Dihedral Angle in the Wings. This will decrease the climb and speed of the aeroplane; also in rough weather, the aeroplane will have a strong tendency to stabilize itself, giving a continuous rocking movement to the machine, owing to the large dihedral angle. The larger the dihedral angle in the wings, the less efficient they become, due to the decreased horizontal equivalent. Any inaccurracy in rigging that must be counteracted for, by the controlling surfaces, detracts from the efficiency of an aeroplane. The aviator, having to hold pressure on a controlling surface to offset the defective rigging, loses much of his judgment in controlling the machine.

BOWING OF THE WING STRUTS.

This is caused by defective wing struts or flying cables with too much tension on them.

To Remedy: In the former case, replace with new struts and in the latter case relieve the added compression on wing struts by taking off the extra tension on the flying cables.

A practical test for the correct tension of the flying cables can be made by the mechanic placing the thumb and first finger at the intersecting point of the landing cable with the flying cable. To be at the correct tension, the flying cable can only be moved one inch up from the point now being held. This determined distance has been proved by practical experience to give the correct tension when the loads are transferred from the landing to the flying cables.

This transferring of the loads will take place when the machine leaves the ground.

A MODERN COMBAT BIPLANE

THEORY OF FLIGHT

Previous to this chapter the machine has been considered as standing on the ground. All calculations and measurements have been based on a fixed object. The definitions have been derived from the concrete. In considering the theory of flight, it will be found that a few definitions will vary with the conclusions brought forward from the rigger's viewpoint, but these should not trouble one who has grasped the study offered in the previous chapters.

It is a well known fact that air has weight. Therefore, it has volume and density. Air is subject to motion which will form currents and eddies. The motion of air may be compared to the motion of water producing eddies that tend to carry anything in its path in the direction of motion. It is due to these currents that the well known "bumps" are encountered during flight. Not long ago these bumps were called "air pockets," and were supposedly caused by a vacuum space in the air. Now it is true that the density of the air varies, especially under a mottled sky when there is strong sunshine, but the variation is never great enough to produce the once talked of vacuum pockets.

Air has resistance to motion, and this resistance varies directly as the square of the rate at which the object is forced through the air. It follows that the greater the surface offered to the direction of motion, the force necessary to maintain a uniform speed must be proportionately greater.

$$\text{Formula: } R = KAV^2 \left\{ \begin{array}{l} \text{where } k = \text{a coefficient varying with} \\ \qquad\qquad \text{the size of the surface} \\ \quad A = \text{the area of the surface} \\ \quad V = \text{the velocity} \\ \quad R = \text{resistance} \end{array} \right.$$

Where there is a resistance there is also a reaction and it is this

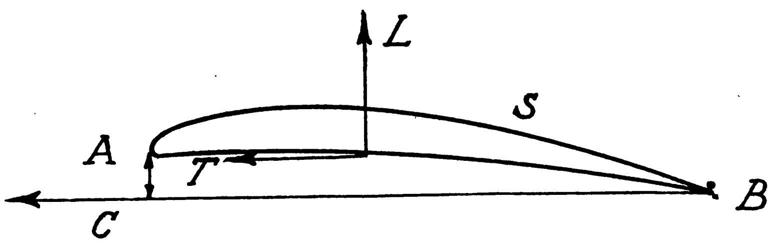


Fig. I.

reaction which produces the lift necessary to keep an aeroplane in the air. A cambered plane A. B. is inclined to the direction of motion at an angle of incidence Fig. 1 ABC. It is forced

through the air in the direction AC. The surface S of the plane AB offers a certain resistance and this has a reaction L, which produces the necessary lift to keep the plane AB in the air. Supposing the velocity to remain the same and the angle of incidence with the direction of motion to increase; then the lift will increase but from the above formula it will be seen that the force T must also increase if a uniform speed is to be maintained. On the other hand if the force T remains the same, and the angle of incidence is decreased; then the velocity increases, due to a smaller resistance.

From these fundamental laws it will be seen that an aeroplane may be kept in flight, by forcing it through the air at such a rate of speed that the reaction on its lifting surfaces is great enough to overcome gravity.

There are four forces acting on an aeroplane that keep it in flight:

1. *Weight*—Acting through the centre of gravity of the machine.
2. *Lift*—Which opposes gravity and acts as a positive force along the vertical.
3. *Thrust*—Which forces the machine through the air, and acts along the axis of the propeller shaft.
4. *Drift*—Which is the resistance the machine offers to the direction of motion, and opposes the thrust. Drift may be divided into three classes:
   - (a) Active drift, which is the resistance offered by all parts of the machine, which act as lifting surfaces.
   - (b) Passive Drift, which is the resistance offered by all parts of the machine, which do not tend to produce lift.
   - (c) Skin friction, which is the resistance offered to motion by the finish on the exposed parts of the machine.

Any number of parallel forces acting on an object may be considered as a single force acting at a point, which will be equal to the algebraic sum of the forces acting through a point called the "centre of forces." In dealing with the four forces—weight, lift, thrust and drift, consider each as a single force acting through its centre of forces.

Illustration No. 2 shows the four forces acting on a cambered surface.

It will be seen that lift opposes weight, and that drift opposes thrust; also, that weight and drift are the two detrimental forces, while thrust and lift are the two helping forces. In order that

an aeroplane can be in equilibrium, the four forces acting upon it must be equal in equilibrium. In other words, *lift* must be equal and opposite to *weight; thrust* must be equal and opposite to *drift*.

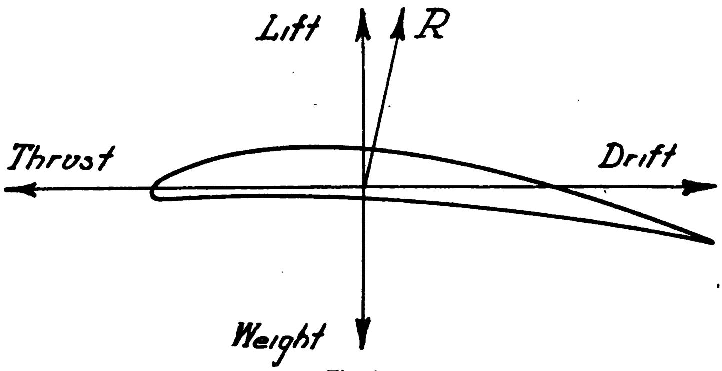


Fig. 2.

Supposing this to be so, then the four centres of forces must meet in a point. Unfortunately this is not practical in the construction of an aeroplane. This being so, a compromise is brought about by having the *algebraic sum of the moments about any point in the machine equal to zero.*

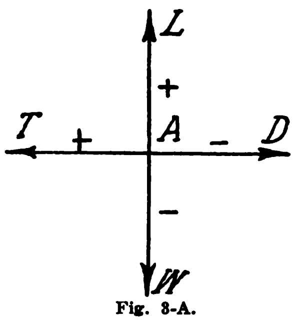


Fig. 3-A.

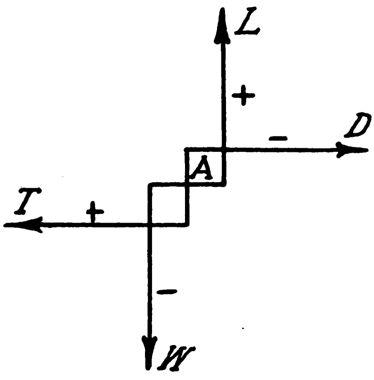


Fig. 3-B.

This is shown in the figures A and B. In figure A, the four forces meet in the point A, and are in equilibrium. In figure B, the four forces form two couples about the point A, and are in equilibrium about that point.

Any two forces may be resolved into a resultant force. Illustration No. 4 shows this by means of the parallelogram of forces.

AB and BC are two forces meeting in the point B. BD is a diagonal of the parallelogram ABCD and is the resultant of the two forces AB and CD in both magnitude and direction.

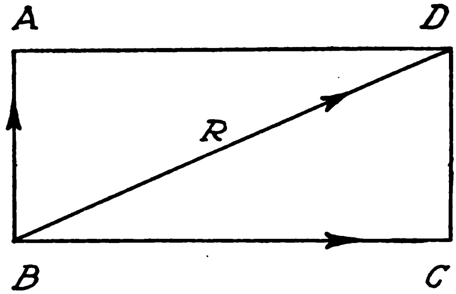


Fig. 4.

In an aeroplane there is a force "drift" acting in a negative direction along the horizontal, and a force "lift" acting in a positive direction along the vertical. The resultant of these two forces is known as the reaction on the plane, and always acts at right angles to the surface of the plane.

The efficiency of an aeroplane depends upon the relation of *lift* to *drift*. As drift is the detrimental factor, it is eliminated as far as possible in the construction of the machine. As already shown any object that is thrust or forced through the air offers resistance to the direction of motion, but this object may be given such a form that the resistance is decreased to a great extent.

To stream line an object is to give it a form that offers the least resistance to its motion through the air. It has been found that an object of an egg-shape section allows the air to unite more readily than that of any other form. If the air does not unite close to the trailing edge of the form, then eddies will result in a similar manner to the eddies formed behind an object that is drawn through water. These eddies are caused by the partial vacuum that is formed towards the trailing edge. The resulting suction retards the speed of the machine and offers one of the largest factors to that detrimental force drift.

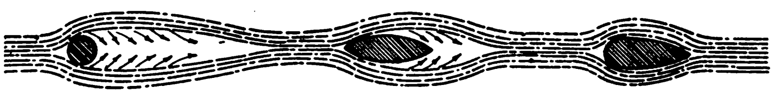


Fig. 5-A. Fig. 5-B. Fig. 5-C.

Consider the forms shown in the illustrations as being placed in a wind tunnel and a jet of smoke set so that it will play directly on the leading edge of the form.

In figure A it will be seen that the smoke is divided on striking the circular form and does not reunite until it has traveled a considerable distance beyond the trailing edge of the form. The

space directly behind the form is filled with curly wisps of smoke that have been drawn in by the partial vacuum, which is present.

In figure B the zone of eddies is somewhat smaller, but it will be seen that the pointed entering edge divides the air and deflects it at such an angle that when it strikes the broadest portion, it is prevented from conforming to the sides of the object. In figure C the air is seen to unite close to the trailing edge and practically no eddies are formed.

In general a well stream-lined object is three times as thick as it is broad, and its broadest part is situated one-third of the distance back from the entering edge as shown in the illustration.

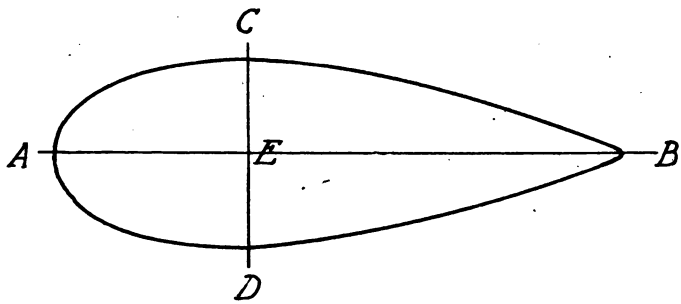


Fig. 6.

AE = ⅓ AB
CD = ⅓ AB

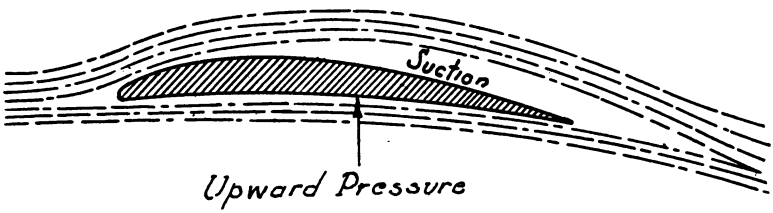
The general outline of a modern aeroplane is stream line in form, and all exposed parts are stream lined where it is possible to make them so. The struts are a notable example of stream-lining, but the practice of stream-lining wires as used on the present day machines probably eliminates a greater percentage of drift than it is generally known to accomplish. When this feature was first brought out in Europe, it was found to increase the speed of a machine from sixty, to seventy miles an hour. Since that date, the aim has been not only to stream-line all wires, but to do away with the external bracing wires wherever it was found feasible to do so. A wire causes eddies to form throughout its full radius of vibration, and as shown before, these eddies are of great assistance to the detrimental factor *drift*.

The old type of a flat plane has been entirely done away with where a surface is designed to produce *lift,* and the modern cambered surface offers a greater resistance to motion; but without this, it would be impossible to maintain the necessary climbing speed which forms such an essential factor in the performance of the modern fighting machine. The degree of curvature and camber is derived through experiment in the wind tunnel. The degree of curvature is seldom if ever constant throughout the chord of the plane, as it is designed to eliminate drift as far as

possible, but at the same time to produce a reaction which will give the required *lift*.

Strange as it may seem, the resulting lift is greater on the upper surface of the plane than it is on the lower surface. This is due to the fact that the curve on the upper surface of the plane deflects the air in such a manner as to leave a space of less density on the upper surface, and thus decreases the pressure on that side. The resulting eddies that are formed also produce a suction, and it has been found by research that approximately three-fifths of the lift is produced on the upper surface, and two-fifths on the lower surface. Apart from the fact that the upper surface is subjected to the weather more than the lower surface, the reaction on it tends to deteriorate it more than that of the lower surface.

The accompanying illustration shows the action of an air stream on a cambered plane.



A DISCUSSION ON LIFT DRIFT RATIO:

It was stated above that the efficiency of an aeroplane depended upon the relation of lift to drift. Therefore, in designing an aeroplane this factor must be kept in view. Practically every factor in the construction of a machine bears directly on this ratio.

The active drift increases proportionately with the velocity, but at the same time the resulting lift is also increased and this counteracts the increase of the active drift until the angle of incidence has been increased to such a degree that the thrust is overcome by the drift. The machine then loses its flying speed, and the reaction is greatest along its horizontal component drift.

The passive drift also increases proportionately with the velocity, and as this factor does not produce any lift, the advantages of stream lining will be clearly shown.

The angle of incidence, as understood in the study of the theory of flight, is the angle that the planes make with the direction of motion. Since there is a positive force acting along the horizontal, and another positive force acting along the vertical, it will be seen that the resulting motion of the plane will be along a line somewhere between these two forces and will be the resultant of a parallelogram of forces where the thrust is one component, and the lift the other component. The angle that the planes make with this resultant is taken as the angle of incidence.

The degree of the angle of incidence given to a plane depends upon the climb-velocity ratio desired, and varies proportionately with the thrust from the propeller. If the thrust is proportionately large, then the angle of incidence may be increased accordingly, producing a greater climb-velocity ratio. This is one of the elements for maximum climb. The average machine combines both climb and speed, and it will be seen that if the angle of incidence is increased, then the drift increases; whereas, if the angle of incidence is decreased, the drift is decreased, and the speed is increased. Generally speaking, a plane is given such an angle of incidence that when the axis of the propeller is horizontal, the machine has the desired climb-velocity ratio, and the reserve power is used to produce a greater speed. If a greater climb is desired, it is obtained by altering the angle of incidence on the main planes in relation to the direction of motion, and naturally results in a corresponding loss of speed along the horizontal.

THE CURVE AND CAMBER:

A planing surface is designed to fulfill the functions it is desired to perform. One that has a large camber and a large curve produces a greater lift than one with a smaller camber and curve, but at the same time the resistance offered by a plane of heavy camber and curve is greater than that of a plane having a finer cross-section. The three factors—Incidence, Camber and Curve work in conjunction with one another.

The measurements for each of these factors are determined by research work in a wind tunnel, and by practical tests in flight. In summing up the elements of lift-drift ratio in relation to the angle of attack, it will be seen that the drift is increased proportionately with the increase in the angle of incidence, the camber and the curve of the plane. The lift is also increased, but the speed is decreased.

THE RELATION OF THE ASPECT-RATIO TO THE LIFT-DRIFT RATIO:

Aspect ratio is the relation of the chord of a plane to the span. From this it will be seen that the greater the aspect-ratio, the greater will be the volume of undisturbed air displaced. The displacement of undisturbed air gives a greater reaction on the planes than that of disturbed air. The reaction is increased in proportion to the amount of air displaced. Therefore, a plane having a high aspect-ratio will be more efficient than one having a low aspect-ratio. In other words, the proportion of lift to drift is increased with a higher aspect-ratio.

There are certain essentials that must be taken care of in the construction of a plane which bear directly on the proportion of lift to drift. The plane must have a certain camber, and a certain curve as derived from the experiments previously mentioned. In

order to establish these, it is necessary to give the plane a certain depth and a certain relative chord. The ratio of the span to the chord must be such that the structural features are mechanically sound throughout, giving the necessary factor of safety to the plane.

STAGGER:

The stagger of one plane above another shifts the centre of pressure on the machine and adjusts the centre of forces in relation to its fore and aft stability. Stagger also enters into the discussion of the lift-drift ratio insomuch that it prevents the disturbed air from the upper surface of the lower plane, from detracting the pressure on the lower surface of the upper plane. In bringing the upper plane forward, the suction on the lower plane acts behind the rear portion of the upper plane, and the two disturbed areas do not encounter each other until at such a distance from the planes that they can have no effect in the reaction.

THE GAP:

It will be seen from the previous paragraph, that as the stagger is increased, the gap may be correspondingly decreased. By decreasing the gap, the struts and wires are shortened with a resulting smaller passive resistance. On most machines, the gap will be found to be approximately equal to the chord of the planes.

THE DIHEDRAL:

A machine having a dihedral angle is given a greater inherent lateral stability than one having no dihedral angle. The resulting lift on a plane varies directly with the horizontal equivalent of that plane, and as the dihedral angle is increased so is the horizontal equivalent decreased, thus decreasing the lift-drift ratio. The tendency has been to design machines with a fairly large dihedral angle, but this feature is gradually being done away with in order to increase the performance of the modern fighting machine.

VELOCITY VERSUS CLIMB:

It has been shown that an aeroplane having a high speed does not necessarily have a great climbing ability and vice versa, a machine capable of maximum climb does not necessarily have a high velocity. As a matter of fact these two qualities work against one another in the performance of an aeroplane. It will be seen from the foregoing remarks that the essentials for maximum climb and maximum speed are directly opposite in nearly every case, and may be summarized as follows:

ESSENTIALS FOR MAXIMUM CLIMB:

1. A low velocity.
2. A large surface.
3. A large angle of incidence relative to the propeller thrust. (Rigger's definition.)
4. A large angle of incidence relative to the direction of motion. (Theoretical definition.)
5. A large camber chord and curve.

The rate of climb may be estimated as follows:

$$\text{Rate of climb per minute} = \frac{H \times 33{,}000}{W}$$

where W = the weight of the aeroplane in pounds.
H = the excess H. P. available
33,000 = the number of ft. lbs. per B. H. P.

It may be generally assumed that the engine develops 75% of its B. H. P. at the speed of maximum efficiency. The lift on an aeroplane may be derived from the formula.

$$L = KRAV^2$$

where L = the lift.
K = a coefficient referring to the angle of incidence
A = the area
V = the velocity
R = the density of the air.

ESSENTIALS FOR MAXIMUM SPEED:

1. A high velocity.
2. A small surface (it should be just great enough to support the weight of the machine in the air).
3. A small angle of incidence relative to the propeller thrust.
4. A small angle of incidence relative to the direction of motion.
5. A small camber chord and curve.

STABILITY:

There are two methods of stabilizing a machine.

1. By the inherent stability given to it by virtue of its design.
2. By the automatic stability which is controlled by the pilot. A machine which is inherently stable answers more slowly to the automatic righting movements of the movable controlling surfaces than a machine which lacks this inherent stability. The machine will frequently be found with a tendency to right itself in one direction, while the pilot wishes to take a shorter route back into the original line of flight. These two righting move-

ments frequently work against one another and sometimes end in the machine being temporarily out of control.

Most machines with an inherent stability will right themselves from whatever difficulty they may have been put in, but the movements are generally comparatively slow, and most pilots prefer a machine that is designed with a stability that is a happy "go-between," the inherently stable machine and the automatically controlled machine. (A machine is said to be stable when it has a tendency to return to the normal line of flight.)

INSTABILITY:

A machine is said to be instable when there is no tendency to return to the normal line of flight after some auxiliary force has thrown it out of its course.

In order that a machine may be readily controlled it should contain a fair stability in the three directions—longitudinally, laterally and directionally.

LONGITUDINAL STABILITY:

A machine is said to be longitudinally stable when it has a tendency to remain in the same fore and aft line of flight. Without this it would have a tendency to dive and climb of its own accord.

LATERAL STABILITY:

A machine is said to be laterally stable when it has no tendency to roll about its longitudinal axis.

DIRECTIONAL STABILITY:

A machine is said to be directionally stable when it has no tendency to vary from its course of flight.

A DISCUSSION ON DIRECTIONAL STABILITY:

If a machine had no directional stability it would tend to swing from its course in any direction and might finally end up in traveling in exactly the opposite direction to that desired.

Supposing a stick, of even cross section throughout, is suspended at its middle point on a pivot. Any slight gust will throw it out of line with the prevailing wind and there will be no tendency for the stick to return to its original position. It will be blown further around in the direction given it by the side gust of wind and will finally end in a direction directly opposite its first position or keep revolving about its central point; but, if a vane is attached to its trailing end, the pressure of the wind on the side of this vane will tend to bring the stick back to a position where the leading end is facing directly into the eye of the wind. An example of this is an ordinary weather vane.

This vane acts as a correcting keel surface, and must be placed so as to act behind the centre of gravity on the object. It will be seen that the greater the distance from the centre of gravity, the greater is the righting moment produced. Hence the longer the lever arm the correspondingly smaller keel surface is required, and vice versa. Therefore, in the construction of an aeroplane, there must be a greater keel surface in effect at the rear of the machine than there is at the front.

Supposing a machine were to lack this directional stability, then in swinging about its centre of gravity, the outer plane would travel at a greater speed than the inner palne and as the lift varies with the speed, the outer plane would have a greater lift than the inner plane with the result that the machine would turn over sideways. It will be seen from this that the lateral and directional stability work in conjunction with one another to a certain extent.

The following illustration will show graphically the righting moment produced by having a greater keel surface in effect at the rear of the centre of gravity:

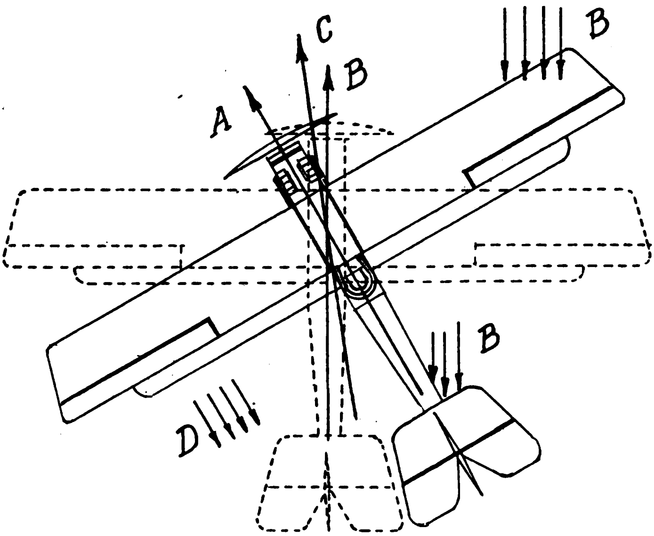


Fig. 8.

Correcting Force Acting on the Keel Surface.

The machine is shown traveling in the direction A. A side gust of wind strikes it from the direction B. This side gust exerts a pressure on the keel surface of the machine, and the greater amount of keel surface being towards the rear, the leverage is greatest from that part, with the result that the machine is turned so that it faces directly into the eye of the new relative wind. But, it will be seen that there is a momentum in the direc-

tion A; therefore, the new direction of motion will be along a line which is the resultant of the two component forces acting in the directions A and B. This being so, there will be a counteracting force D from the direction of the original line of flight, and this acting upon the keel surface "in effect" at the rear of the machine will tend to bring the nose of the machine back into the original line of flight, but at a distance slightly to the side in the direction from which the side gust came.

The righting force D will act only so long as there is a momentum in the direction A. When this momentum stops, then the machine will nose directly into the new relative wind, and its direction of motion will be parallel to it.

Up to this point the inherent stability has been considered. The directional stability is controlled automatically by the movement of the vertical rudder placed at the rear of the fuselage in the direct force and aft line of the machine. By moving this, a greater leverage is obtained by virtue of the increased keel surface offered to the thrust from the propeller.

LATERAL STABILITY:

Every machine has a certain amount of keel surface. If the side elevation of an aeroplane be considered, every part visible to a spectator is a portion of this keel surface. It includes the struts, wires, fittings, the cross section of the wings and the fuselage; also, the movable controlling surfaces and additional vertical fins. There is a resulting centre of pressure for the total keel surface of the machine. It will be seen that the location of this centre of pressure forms a vital factor in the lateral stability of the machine. If it is placed below the centre of gravity of the machine, that is the axis of roll, the tendency of a side gust will be to increase the roll, and will therefore be a disturbing moment.

If the centre of pressure on the keel surface lies on the axis of roll, then the stabilizing effect will be neutral. Supposing the resulting centre of pressure on the keel surface, due to the relative wind, lies above the axis of roll, then the moment of the force produced on the keel surface will be a righting moment. From this it will be seen that the keel surface should be distributed about the axis of roll so that the resulting centre of pressure lies above the centre of gravity. It should not be too great a distance above the centre of gravity, because this would give the machine a tendency to act as a pendulum.

One method of raising this resulting centre of pressure is to increase the dihedral angle on the main planes. This also aids lateral stability in a different manner, as will be shown in the following sections.

Supposing a machine to be in normal flight, then the wings are making equal angles with a horizontal plane, and the reaction

is the same for the planes on both sides of the fuselage. If a gust strikes the surface of the planes on one side of the machine, then the lateral equilibrium of the machine is disturbed.

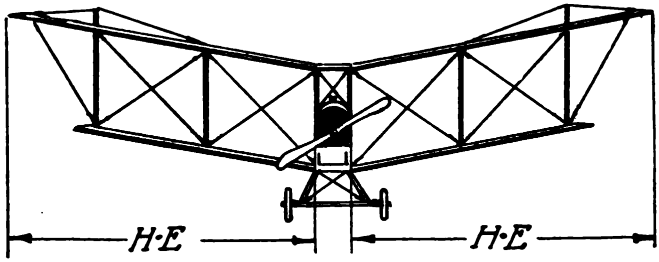


Fig. 9-A.
Machine in Normal Flight.

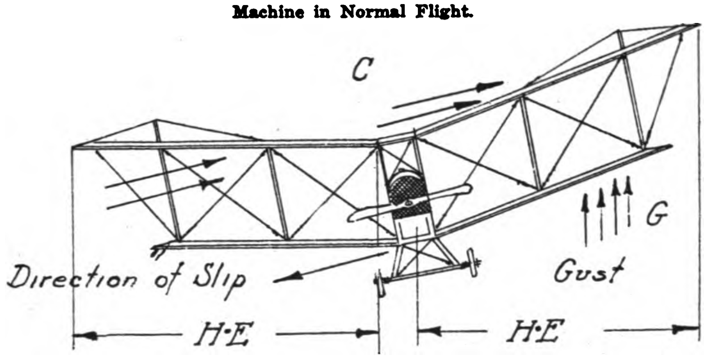


Fig. 9-B.
Machine Subjected to a Gust Under One Plane.

Figure A shows the machine in normal flight and in equilibrium. Figure B shows the effect of a gust of wind under the left wing. The new force G increases the pressure on the left wing, and so raises it. The right wing drops a corresponding distance. The machine not being in a state of equilibrium, is acted upon by gravity and side slips in the direction D. The machine tends to turn into the new relative wind D, but there is a counteracting force C which exerts a pressure on the lower surface of the right wing, and on the upper surface of the left wing. This resulting pressure tends to right the machine, so it will return to its normal flight, but at a slightly lower altitude than its first course.

The greatest lateral stability is obtained by the dihedral angle due to the difference in the horizontal equivalents when a gust of wind under one wing has upset the state of equilibrium.

In the preceding figure A, it will be seen that the horizontal equivalent is the same for both the right and left wings. In the figure B, the horizontal equivalent is greater for the right wing

than it is for the left wing. Since the lift varies with the horizontal equivalent, it will be seen that there is a greater lift on the right wing than on the left. This increased lift will raise the right wing until the horizontal equivalents on both wings are equalized.

When a machine is turning it is put into a Bank, i.e., the machine is tilted sideways. In a perfect turn, the machine will stay in equilibrium and there will be no tendency for it to side slip. The inner wing will travel at a slower rate than the outer wing. Therefore, the pressure on the outer wing will be greater than that on the inner wing, but it will be seen from figure B that the horizontal equivalent of the inner wing is greater than that of the outer. The increased lift, due to the greater horizontal equivalent on the inner wing compensates the increased lift, due to the greater pressure on the outer wing; so the lateral stability is maintained.

Lateral stability is automatically maintained by the pilot through warping the wings or ailerons. In doing this, the pilot increases the angle of incidence on one wing or part of it; and decreases the angle of incidence on the opposite wing, thus controlling the ratio of the lift on the two wings.

LONGITUDINAL STABILITY:

A machine should be so designed that when the engine has been throttled down or stopped, it will naturally take up its own gliding angle, and without further aid from the pilot, maintain a safe flying speed until it has reached the ground. This is brought about by having the centre of gravity placed slightly forward from the centre of pressure. The exact distance that it should be placed is based upon the gliding angle of the machine. The gliding angle depends on the load carried and the total resistance offered by the machine. It may be determined from the following formula:

$$\text{Gliding Angle} = \frac{\text{Total Weight}}{\text{Total Resistance.}}$$

The average machine has a gliding angle of about one in five. In other words, it will glide approximately one mile for each thousand feet of height.

The flat plane as used on the earliest types of aeroplanes was found to be very inefficient, but it had the one advantage of being stable.

The cambered plane is found the most efficient, but unfortunately, it is unstable.

The centre of pressure on a plane varies with the angle of incidence. In a flat plane it is situated at its middle point when the plane has an angle of incidence of 90°. As the angle of inci-

dence is decreased, the centre of pressure moves gradually forward until at 0° it is situated at the leading edge of the plane. It will be seen, that as the machine is "nosed down" the centre of pressure is brought forward, and has a tendency to bring the plane back into its original position.

When a cambered plane is set at an angle of 90° to the direction of motion, the centre of pressure is at its middle point, and as the angle of incidence is decreased, the centre of pressure moves slowly forward towards the leading edge until the plane is inclined at an angle of about 30°. The centre of pressure then moves rapidly forward until the plane is inclined at an angle of about 15°. At this point the centre of pressure starts to retreat towards the trailing edge at a rapid rate, and at 0° incidence, it is located slightly back of the centre line of the plane, as shown in the following illustration.

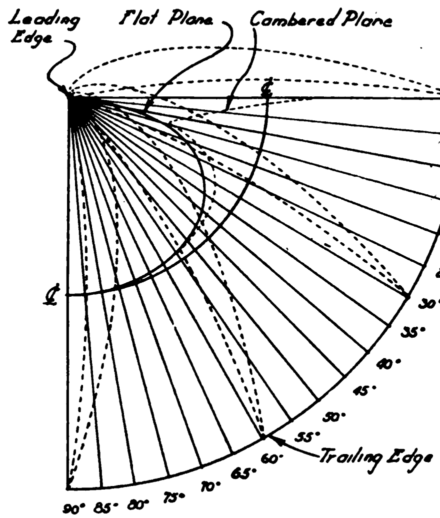


Fig. 10.

It will be seen from this that as the angle of incidence is decreased from the ordinary climbing angle, the centre of pressure moves backwards and tends to accelerate the "nose-diving" of the machine. In order to counteract this instability of the cambered planes, it is necessary to use an auxiliary righting plane, situated at some distance from the main planes. This is accomplished by means of the horizontal stabilizer and the elevators. The reaction of the righting moment produced on these surfaces acts along a lever arm, which is the fuselage, and compensates the instability on the main planes. It will be seen that the longer

the fuselage, i.e., the lever-arm, the smaller need be the surfaces of the horizontal stabilizer and the elevators.

THE PENAUD TAIL PRINCIPLE:

This principle brings forth a rule, i.e., the angle of incidence on the tail plane must be less than the angle of incidence on the main planes. This principle takes care of the fact that the disturbed air from the main planes is deflected downwards, and although the horizontal stabilizer may have an angle of incidence in relation to a horizontal plane, it may be placed directly into the eye of this deflected wind, with the result that it is a non-lifting tail.

The following illustration will show the righting moment exerted by this difference in the angles of incidence.

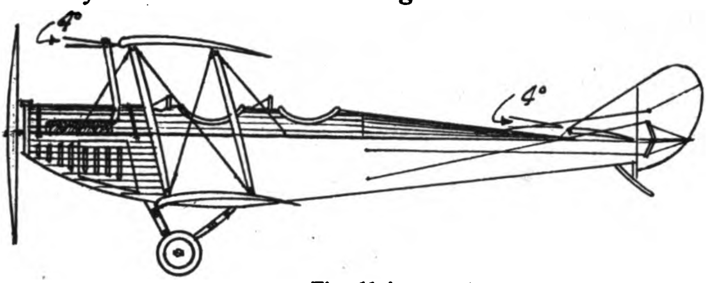


Fig. 11-A.

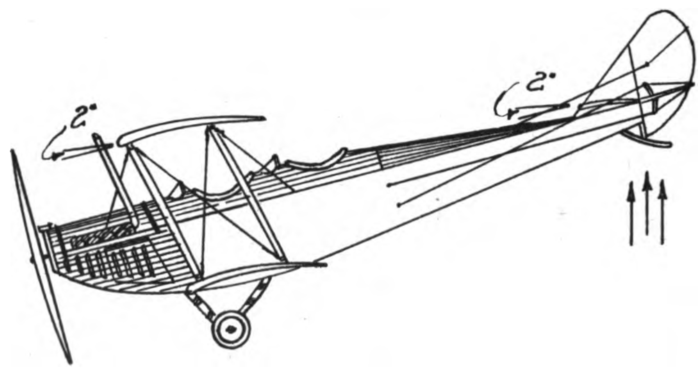


Fig. 11-B.

Suppose, for the case of illustration, that the main planes are set at an angle of incidence of 14° with the direction of motion and the horizontal stabilizer set at an angle of incidence of 4° as shown in figure A. The machine receives an upward gust as shown in figure B, which tends to move the machine down until the main planes have an angle of incidence of 12°, and as the horizontal stabilizer is attached rigidly to the longerons it will

lose an equal amount of its angle of incidence, which now equals 2°. From this it will be seen that the main planes have lost only one-seventh of their angle of incidence, while the horizontal stabilizer has lost one-half of its angle of incidence. As the lift varies with the angle of incidence, the main planes have lost less of their lift in proportion to the loss of lift on the tail plane. The reduced lift on the tail plane will allow it to drop, and the resulting leverage on the main planes will bring them back until the angles of incidence are the same as in figure A, providing the movable elevators remain in the same relative position. So it will be seen that the Penaud Tail Principle tends to make a machine longitudinally inherently stable, and will cause the machine to assume its original position, but always at a slightly lower altitude.

The longitudinal stability is automatically controlled by the pilot in moving the elevators. In doing this, the angle of incidence on the tail plane is increased or decreased, and the resulting pressure changes the angle of incidence on the main planes.

In summing up the location of the various centres of forces, it is generally found that the centre of thrust is situated in front of the C. G., and below the centre of drift. The centre of drift is situated in front of the centre of gravity, but below it. The centre of lift is situated behind the centre of gravity, and above

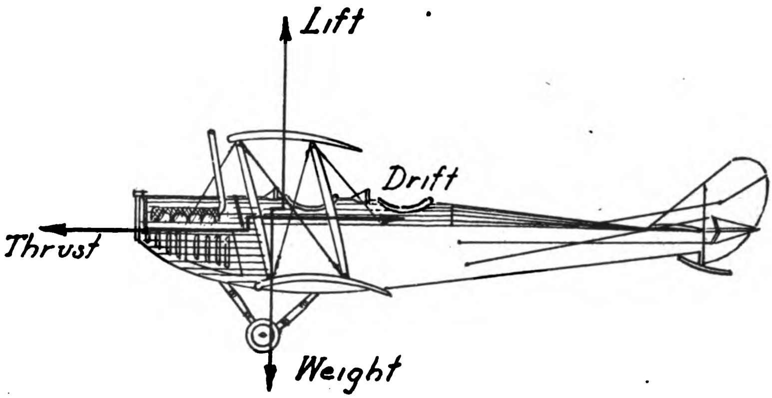


Fig. 12.

the centre of thrust. The centre of gravity is situated just behind the engine and gravity fuel tank, and about two-thirds of the distance up from the bottom of the fuselage.

The resulting couples are so situated as to keep the machine in equilibrium during flight.

SPINNING AND LOOPING.

SPINNING:

To the uninitiated a "tail spin" is generally more or less of a startling experience. It combines the thrills of nearly all the other "stunts" and at the same time has a bewildering effect upon the controls. A tail spin may be caused in two ways: First, by stalling the machine in a turn, the direction of which is opposite to the rotation of the propeller. Secondly, by misusing the controls, such as pressing the rudder in one direction, while warping the ailerons for a turn in the opposite direction.

In the first case, the flying speed is abnormally low. In the second case, the machine may have a normal flying speed or greater.

THE CAUSES OF SPINNING:

1. The fin surface aft may be inadequate.

2. The rudder reaction may be too strong for the pilot to correct it.

3. At speeds below normal flight, the operation of the ailerons may produce a spinning tendency, which the fin and rudder, though otherwise adequate, are unable to counter.

4. The fin surface may be unsymmetrical about the fore and aft center line of the machine.

5. The error that causes most spins is that of allowing the speed of the machine to get too low, while attempting to turn.

When a machine is placed in a bank for a turn the horizontal equivalents of the wings are decreased. Hence the lift is decreased. The proportion of the two forces *drift* and *weight* to the forces *thrust* and *lift* is increased. As the speed is decreased, the action of the detrimental forces weight and drift is proportionately increased, with the result that the state of equilibrium in the machine is upset.

A spin will generally start with a slow turning motion, pivoting about the nose of the machine. The center of gravity being situated towards the front of the machine gives the nose of the machine a tendency to drop. As the nose drops, the radius of the spin decreases, but the speed increases. Most aeroplanes will stop spinning when the nose is pointing vertically downwards, and when the necessary flying speed has been picked up the pilot may pull back on his control yoke and bring the machine into flying position and have it under control once more. It will be found that the automatic controls on most machines will fail to work in a spin, except that a slight reaction may be obtained from the elevators. The machine has a tendency to realign itself with the new relative wind, which is constantly changing until the machine is in the vertical nose dive,

METHODS OF OVERCOMING A SPIN:

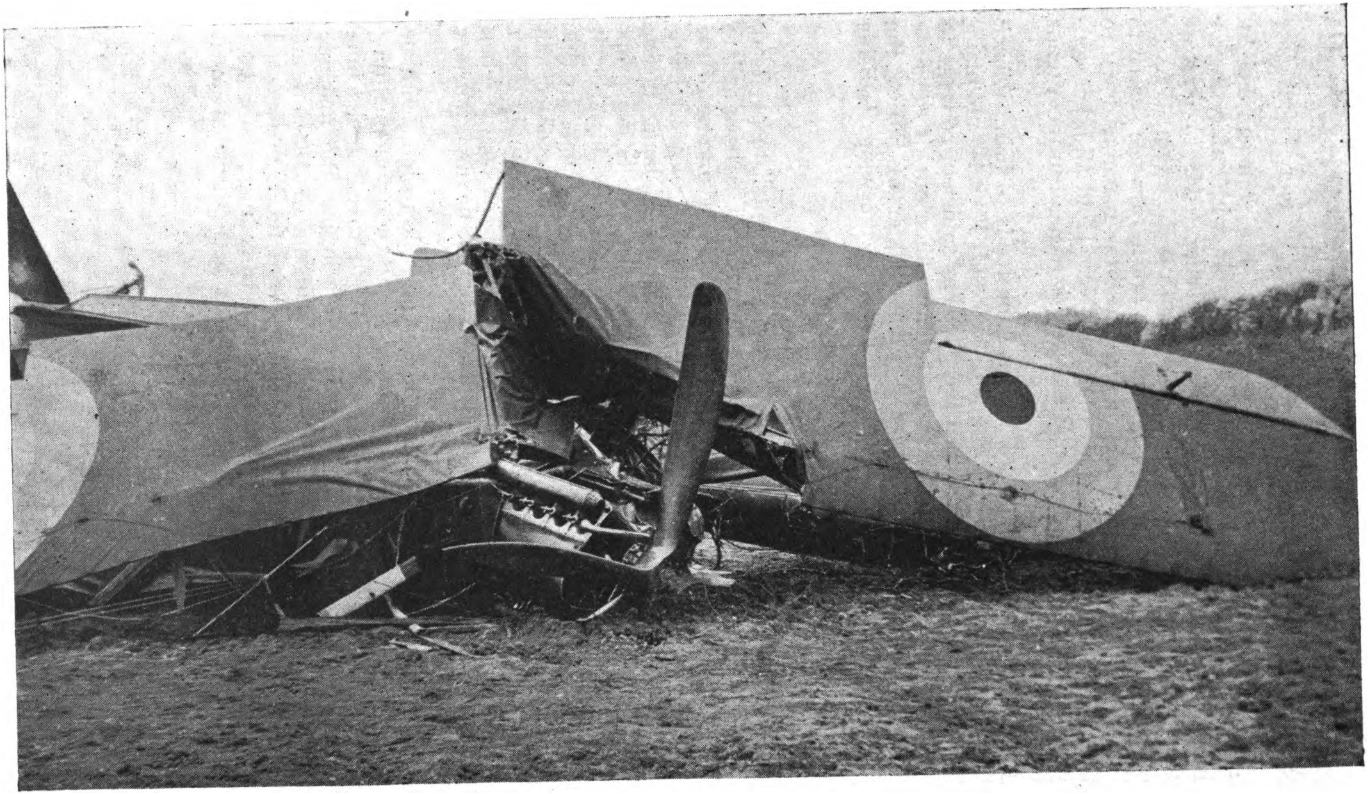
It is first essential that the machine has sufficient height. Most machines can be brought out of a spin with safety in five hundred feet. The Torque of the propeller tends to increase the spin, so the first thing to do is to shut off the engine. As an extra precaution against fire in case of a crash, turn the switch to "OFF." If there is sufficient height, nose the machine down to pick up the flying speed as soon as possible. Hold all other controls neutral, as it will be found that any movement in them tends to increase the spin.

The inherent stability of the machine tends to bring it back to flying position, and if the engine is kept "OFF" it should maintain its own gliding angle until the pilot has sufficient courage to try it again. Never attempt to pull the machine out of the nose dive too suddenly unless there is great danger of hitting the ground, as the extra heavy load produced on the wings is liable to crumple them.

LOOPING:

Looping is probably one of the easiest "stunts" to perform, providing the machine has sufficient power, and is designed to withstand the heavy strains produced in the rapid changing of the angle of incidence. In a perfect loop the centrifugal force holds all movable objects in place, and the sensation of being upside down is not very noticeable. If, however, the loop is not properly carried out, the sensations may be varied. For instance, it is possible to fly upside down for a considerable time. In this case the centrifugal force is eliminated, and the loose objects in the cockpit are liable to fall out. This condition is brought about in certain machines by failing to throttle down the engine when the top of the loop has been reached, or by not having sufficient momentum to carry the machine around.

In some of the later machines, it is possible to loop without first nosing the machine down to gain the necessary momentum; but in the ordinary type, it is necessary to dive the machine steeply before attempting the loop. In bringing the machine out of the dive, use a gradual pressure bringing the machine up on the inside of a perfect circle. On some of the high powered scout machines, it will be found necessary to counteract the lack of the engine torque when the engine has been throttled down on the top of the loop.



FINIS.